**HARDING UNIVERSITY**

# Final Design Review

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# Project Overview and Status

**Pill Storage and Dispensing Mechanism**

It was clear from the construction of previous prototypes during the fall that proper connection between all of the mechanical components would be a major issue. One of the most important mechanical connections is that between the pill storage bin and the auger-casing mechanism. Previously, the pill storage bin and the auger-casing mechanism were designed as separate units. This design is shown in Figures 1 and 2. This is a suboptimal design because this design requires the extra work of accurately attaching each pair of these components. A preferable design is shown in Figure 3. In this design, the pill storage bin and the auger-casing mechanism are designed as one seamless unit. This assures that there are no obstruction to the flow of pills between the pill storage bin and the auger casing mechanism.

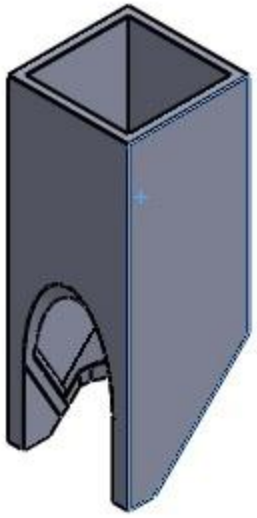


Figure 1. Previous Pill Storage Bin Design

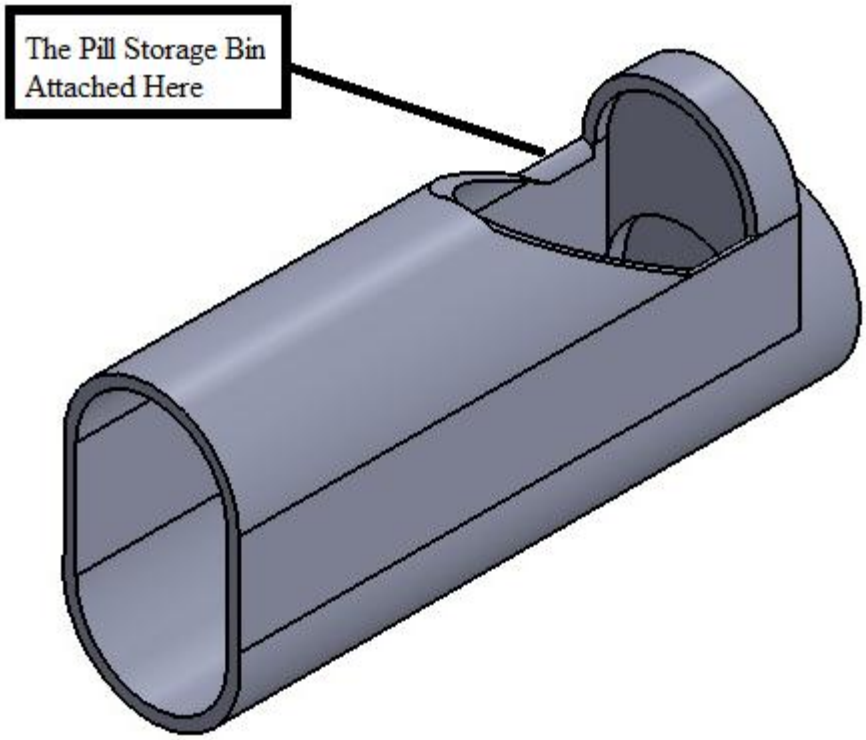



Figure 2. Previous Casing Design

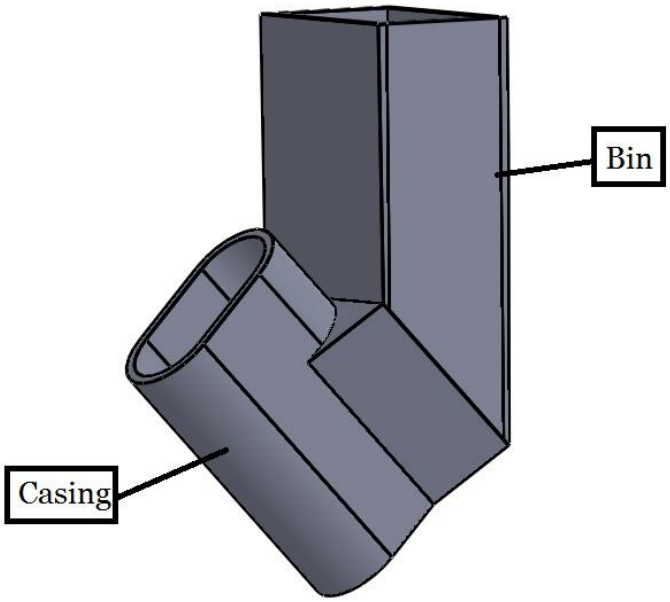



Figure 3. Combined Bin and Casing

To test the design of the pill storage and dispensing mechanism, a new prototype was constructed. A new feature of this prototype that differentiates it from previous ones is that this included a design to synthesize the pill storage and dispensing mechanism with the device housing. The design of the prototype is shown in Figures 4 and 5. The T shown on the back of the bin is the means by which the bin attaches to the rest of the device. This T is designed to slide into bin holders on the device wall. A drawing showing one of these bin holders is shown in Figure 6. In most other respects, this design was the same as previous versions.

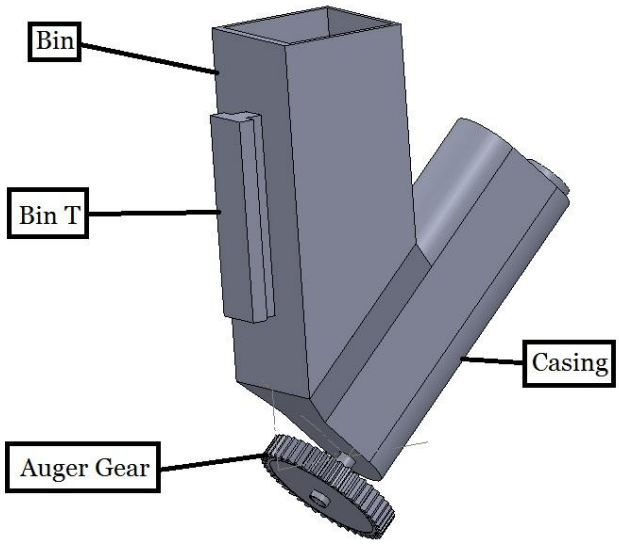



Figure 4. Back view of the prototype Design

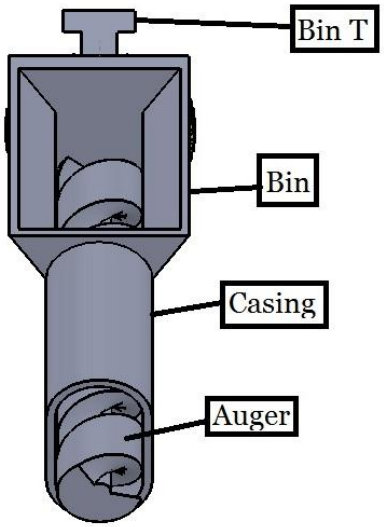



Figure 5. Top view of the prototype design.

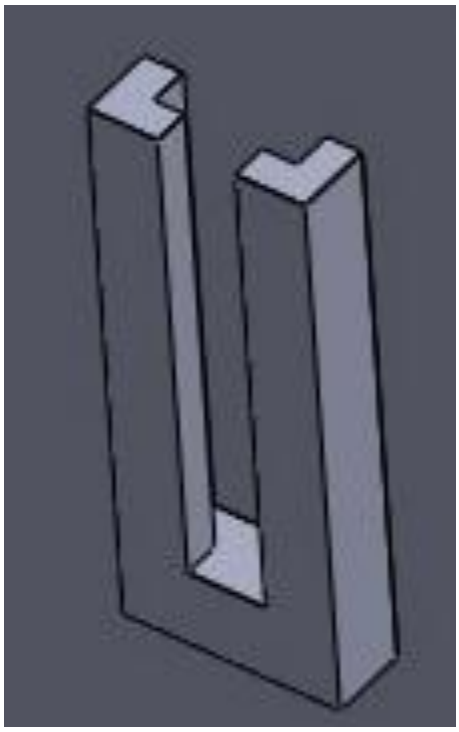


Figure 6. Design of the bin holder

The main purpose of this design is the convenience to the user. The user will be able to easily remove pill storage and retrieval units from the device housing. This allows for easy loading of pills, easy washing of the mechanisms, and customization of the types of mechanisms the user can put into the device. A figure of the design of the prototype is shown in Figure 7. A goal of this prototype was to build a bin slot and motor mount which would guarantee an accurate mate between the auger gear and the motor gear. To achieve an accurate mate between the two gears, two things need to be true. First, the axis of the motor shaft and the axis of the auger must be parallel. The angle of the auger shaft is 45° from the horizontal. This means that the motor mount needed to hold the motor at a 45° angle. Second, the distance between the two gears must be a certain value. This distance is determined by the diameters of the two gears. If this distance is too small, then the design will be impossible because the gears will be taking up too much space. If this distance is too large, then the gears will not mate with each other because they will be separated. The goal was to have two-thirds of the gear teeth overlap with each other.

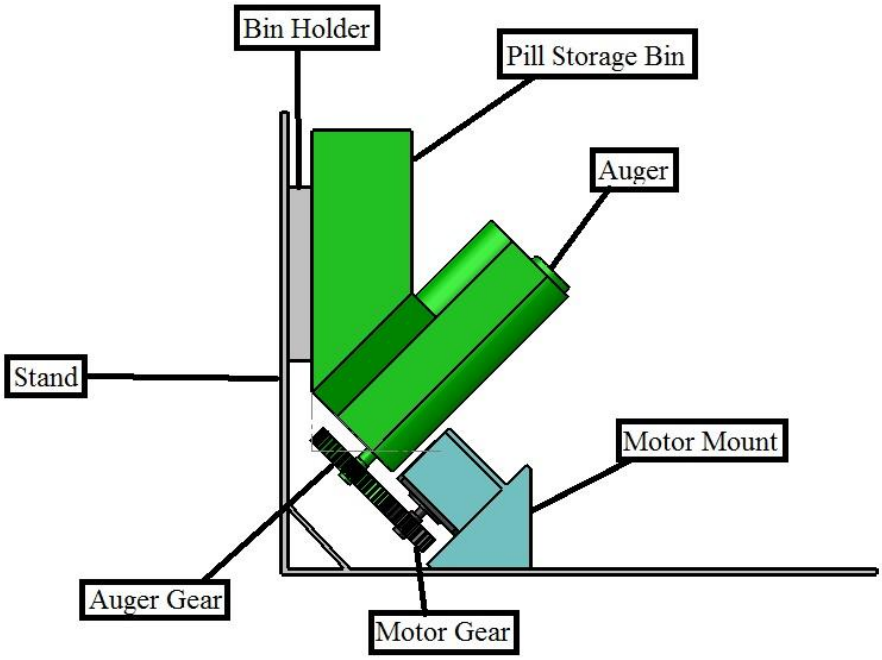



Figure 7. Design of the prototype.

The pill storage bin, the auger, and the two gears were 3d printed. The bin holder and the motor mount were built out of Plexiglas. A picture of the prototype is shown in Figure 8. A closer picture of the bin holder is shown in Figure 9. The lessons learned from this prototype revealed the need for several more changes to the design.

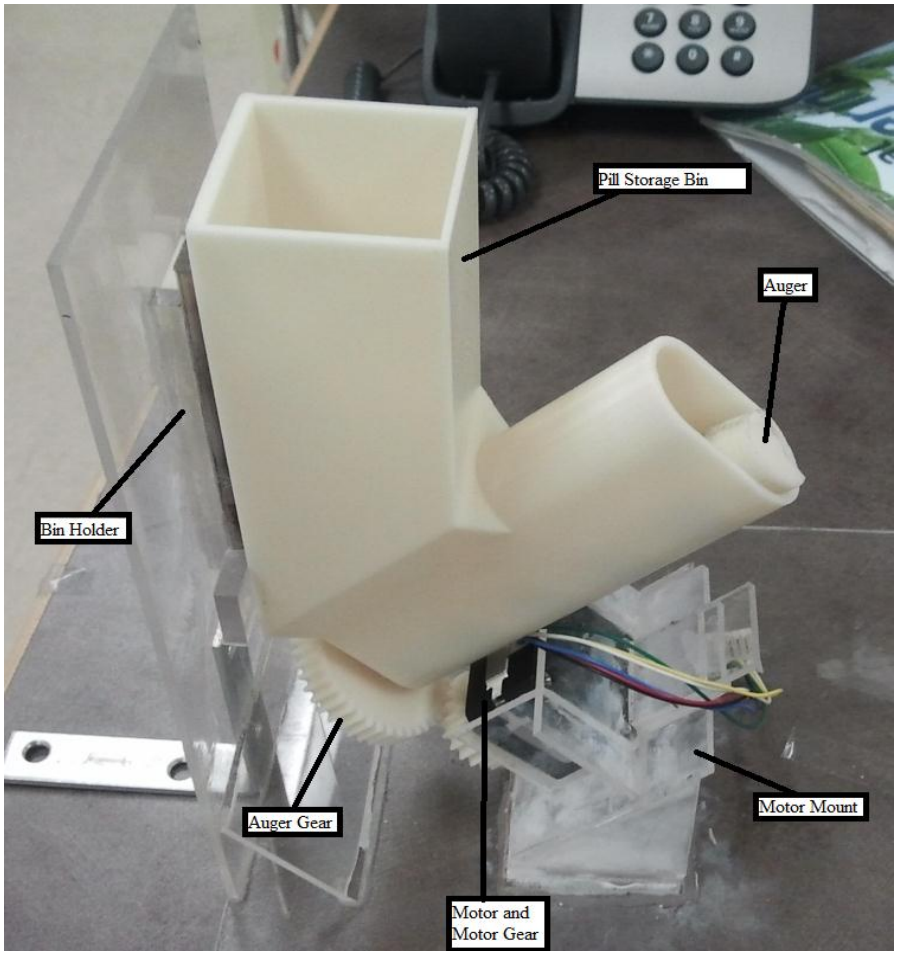



Figure 8. Prototype Build

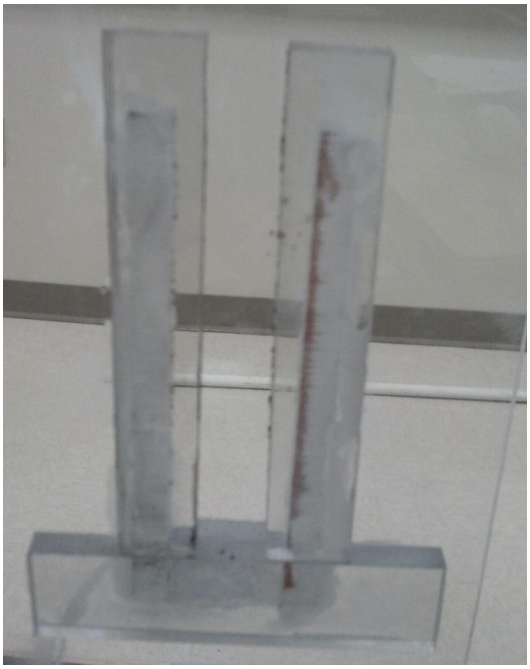


Figure 9. Bin holder for the prototype

The prototype ran successfully with all of the pills shown in Figure 10. Two tests were done for each pill. In each test, approximately twenty pills were placed into the device. All of the pills were then dispensed from the device. In every case, the device dispensed one pill at a time and no jamming occurred. The one exception to this is that there was one minor malfunction with the purple pills on the far right in the photograph. These pills bridged in the device across the slope that connects the pill storage bin to the auger-casing mechanism. This slope is labeled in Figure 11. A photograph of the bridging effect is shown in Figure 12. This bridging only occurred once and was addressed with design changes described later in the report.

Figure 10. Pills successfully dispensed by the device

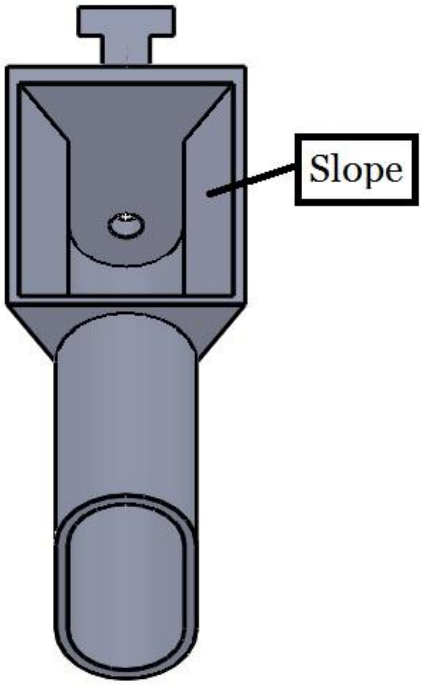



Figure 11. Slope between the bin and the casing.

Figure 12. Picture of the Pill Bridging

There was one type of pill that was not successfully dispensed by the device. This pill is shown in Figure 13. This pill type caused the device to jam. This pill type is unique because it is a disc with a diameter smaller than the disc shaped pill that was successfully dispensed by the device. The dynamics are slightly different for disc shaped pills than for capsular pills because in capsular pills the small dimension is biaxial while in the disc shaped pills the small dimension is uniaxial. There are some design changes to the auger that are intended to alleviate the problem that these disc shaped pills encountered. These changes are described later in this section of the report.

Figure 13. Pill unsuccessfully dispensed by the device.

Even though this prototype ran successfully, the mate between the auger gear and the motor gear was not sufficiently accurate. The motor shaft and auger shaft were misaligned. Figure 14 shows this misalignment. The motor gear would drive the auger gear with some interference. It was clear that a new method was needed to integrate the bin into the device. It was decided that the best method would be to print the bin holders and motor mounts using the 3d printer. Parts made using the 3d printer are much more accurate that those made by cutting Plexiglas with a band saw. The design for the new bin holder is shown in Figure 15. This part will be attached to the device wall using mechanical fasteners. The bolts will go through the holes in the part. Using mechanical fasteners is more accurate than gluing because parts that are in the process of being glued together are susceptible to slipping while the glue is drying. The holes can be drilled into the device wall very accurately using the milling machine that is located in the machine shop in the Harding University Ulrey building. This machine has a digital readout specifying the position of the tool head, allowing for very accurate positioning of the tool head position. This means that the holes can be drilled at where they need to be within acceptable tolerance.

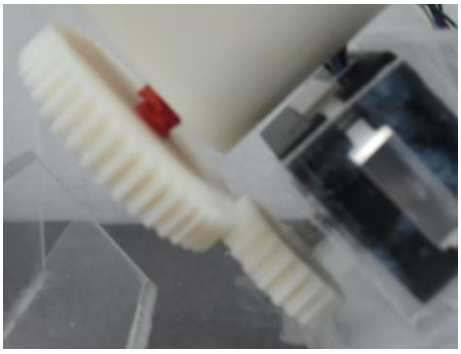


Figure 14. Misalignment between auger gear and motor gear.

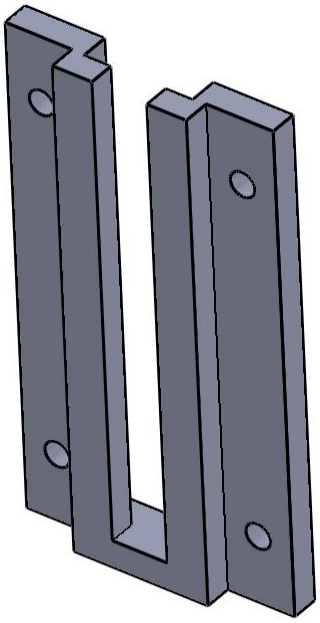


Figure 15. Design of the bin holder.

A similar design process was carried out for the motor mount. The motor mount will be 3d printed to ensure high accuracy. A picture of this design is shown in Figure 16.

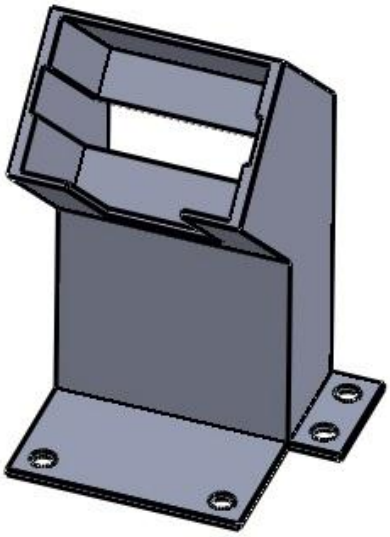


Figure 16. Design of the Motor Mount

The full integration of all of these components with the device housing is shown in Figure 17. This figure is not a drawing of the overall device. It only shows how the dispensing mechanism, the motors, and the device housing integrate together. The holes in the device

housing are designed to match exactly with the holes in the bin holder and the motor mount. Bolts pass through these holes to connect these parts to the device housing. An up close view is shown in Figure 18. Everything is positioned exactly to ensure that two thirds of the teeth overlap in the mating auger and motor gears. Figures 19 shows the layout of holes in one side of the device housing. This will serve as the template for drilling the holes with the milling machine.

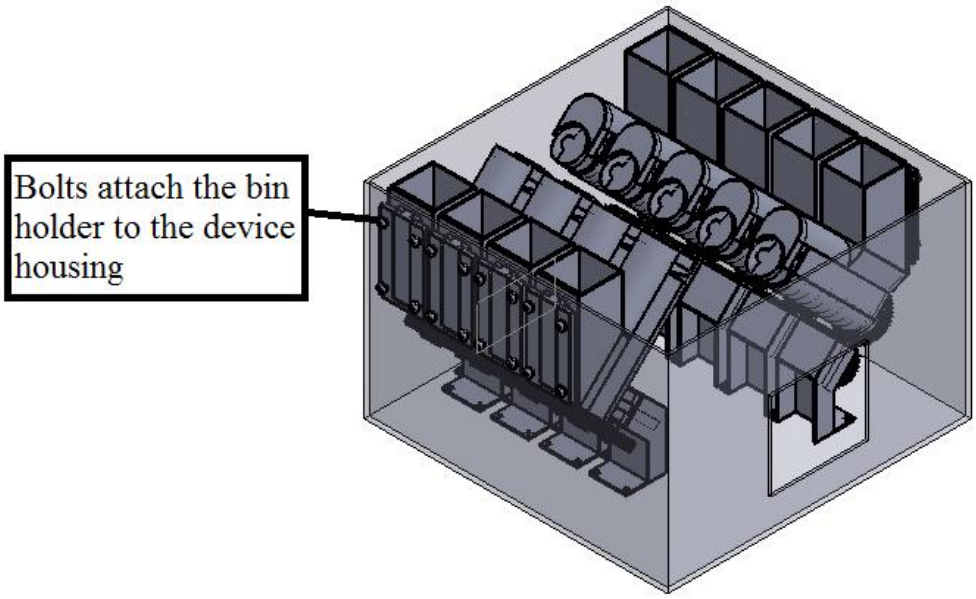



Figure 17. Integration of the dispensing mechanism, motor, and device housing.

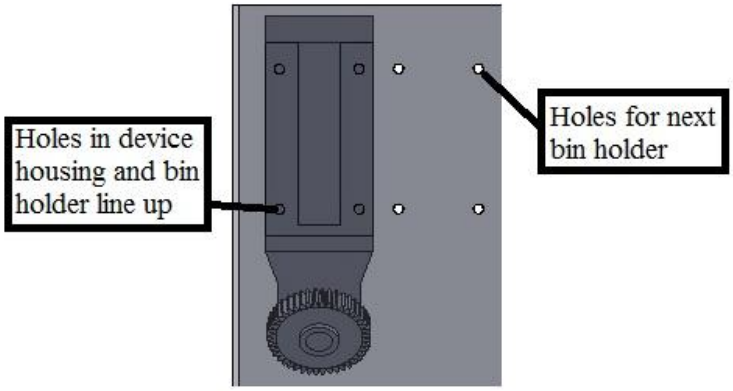



Figure 18. Up-close view of the integration.

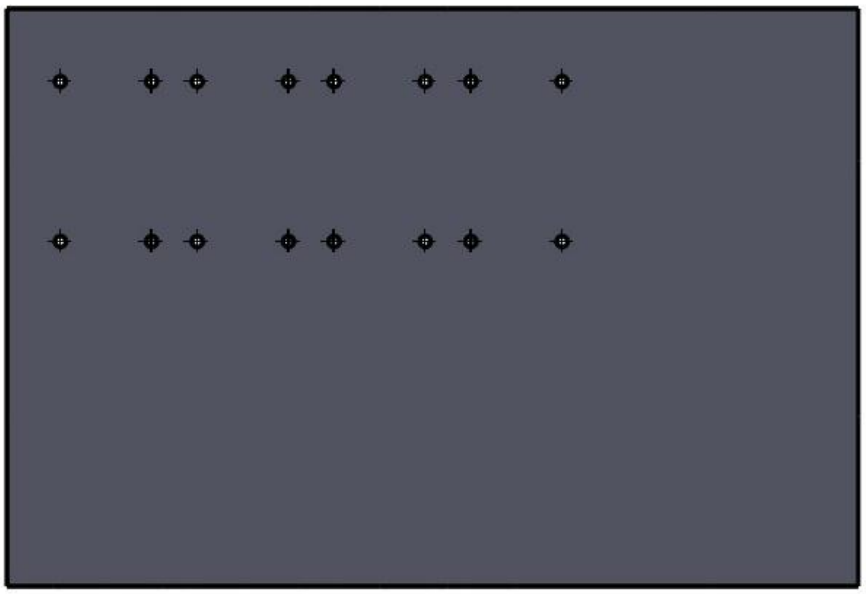


Figure 19. Template for drilling holes in the device wall.

Some changes were made in the design of the auger-casing mechanism. First the minor diameter of the auger was increased from 0.64 cm to 1.27 cm (0.25 in. to 0.5 in). This new auger is shown in Figure 20. This design change should assist with the dispensing of pills that are very long. A prototype that was 3d printed during the fall semester had trouble dispensing pills with a length of approximately 1 in. This was due to problems rotating a long, flat pill with a curved surface. A larger minor diameter means that the surface of the auger will be less curved relative to the pill.

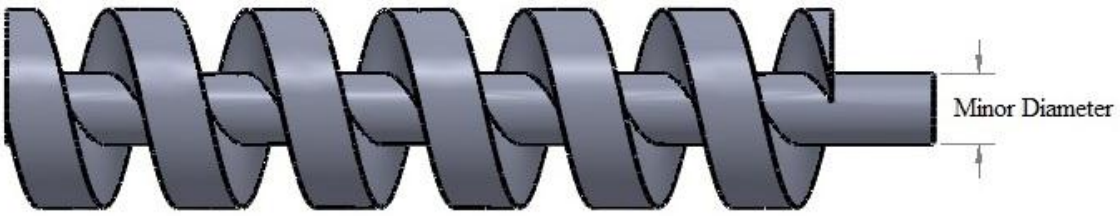



Figure 20. Auger with increased minor diameter.

The second change was done to the casing and is shown in Figure 21 and Figure 22. Additional support was added to the end of the casing. The purpose of this support is to limit movement of the auger. Previously the end of the auger was free to rock upward. This rocking is undesirable due to the risk of pills wedging underneath the auger. A picture of this phenomenon is shown in Figure 23. With this new support that movement will be constrained.

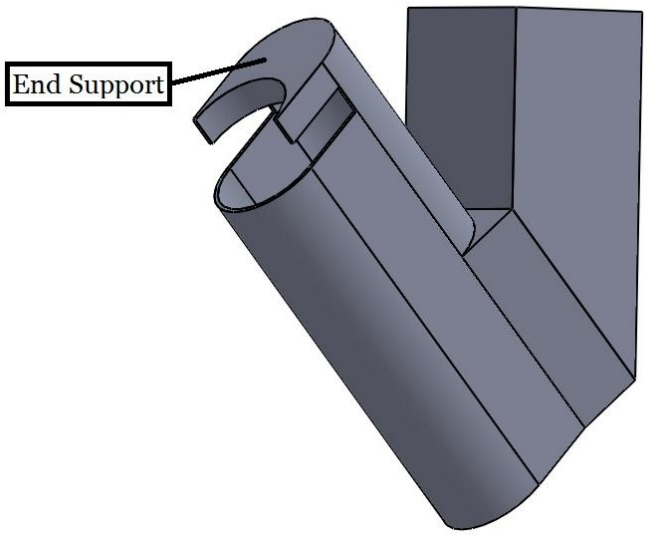



Figure 21. Illustration of the added support at the end of the casing.

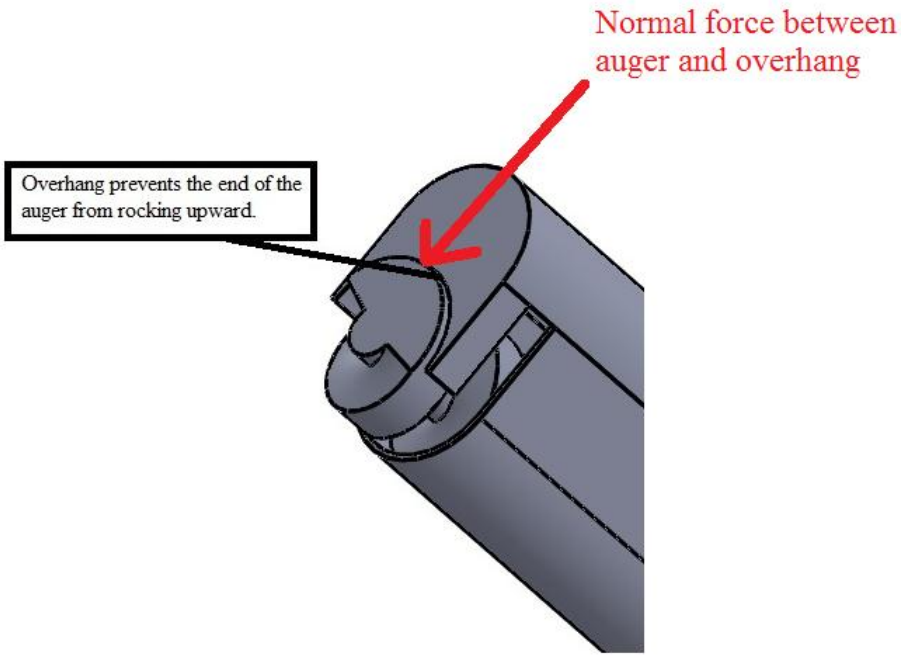



Figure 22. Illustration of the added support with the auger.

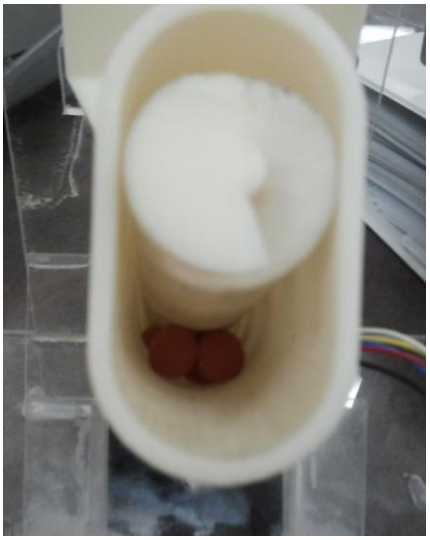


Figure 23. Pills jammed underneath the auger.

The last change was that the slope connecting the bin to the casing was increased. This is illustrated in Figure 24. This change should alleviate the bridging problem encountered during the testing of the prototype. The angle of this slope in the prototype was 60°, which is less than the 70° in the new prototype. The only other way to alleviate this problem would be to shrink the dimensions of the pill storage bin or increase the diameter of the casing. Since these values are already locked by other design considerations, the problem must be solved by increasing the slope of the connection

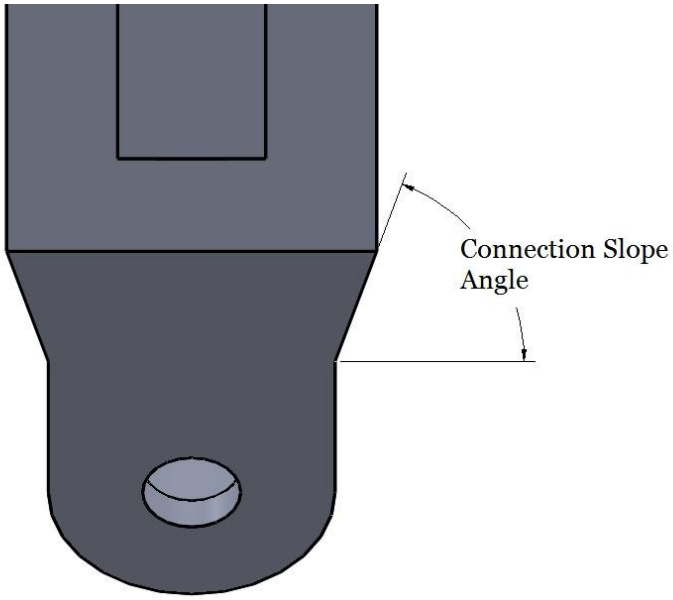



Figure 24. Illustration of the connection between the casing and the bin.

A pill storage and dispensing mechanism intended for larger pills that implemented these design changes was 3d printed and connected to the device housing. A picture of this mechanism is shown in Figure 25.

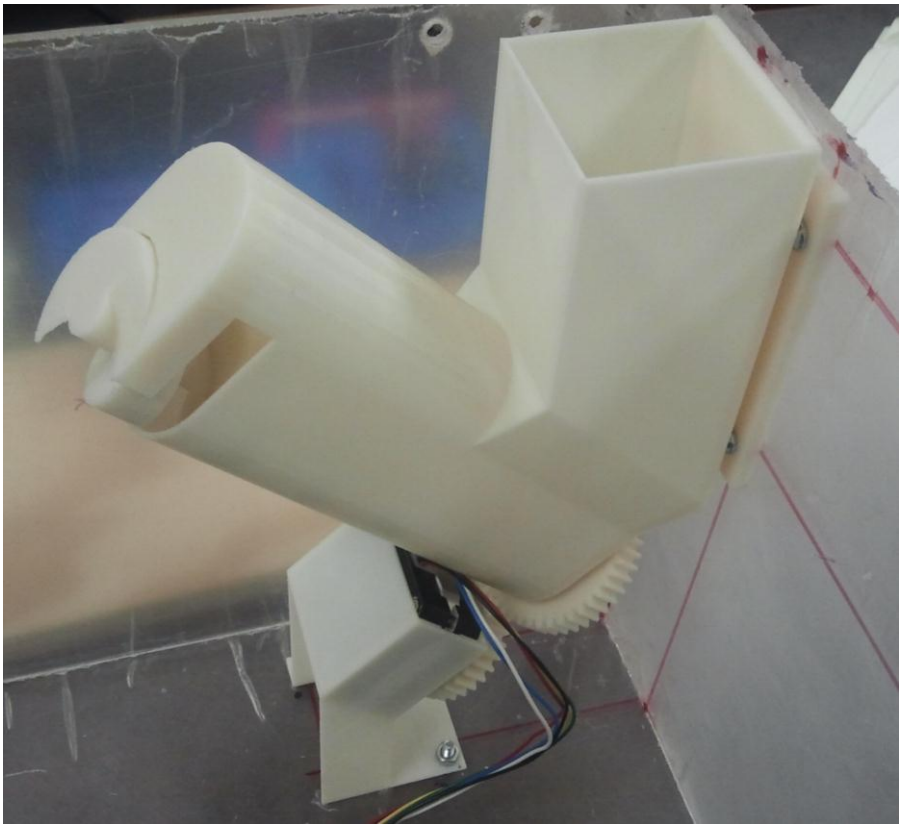


Figure 25. Pill storage and dispensing mechanism connected to the device housing.

This device performed successfully with both of the pills shown in Figure 26. The device dispensed both of these pills one at a time in all tests with no instances of jamming. This device is also successful in achieving an improved mate between the auger gear and motor gear. The device ran much more smoothly and quietly than the previous prototype. This is due to the fact that the auger shaft and motor shaft are parallel, and the distance between the two gears is correct. This allows for an accurate mate between the two gears. A picture of this phenomenon is shown in Figure 27. The only critical flaw in the device is that it sits too high in the device housing. The lid of the device housing cannot shut properly. For this pill storage and dispensing mechanism this will be alleviated by cutting off some of the top of the bin. All future models will be designed to sit lower in the device.

Figure 26. Pills successfully dispensed by the device.

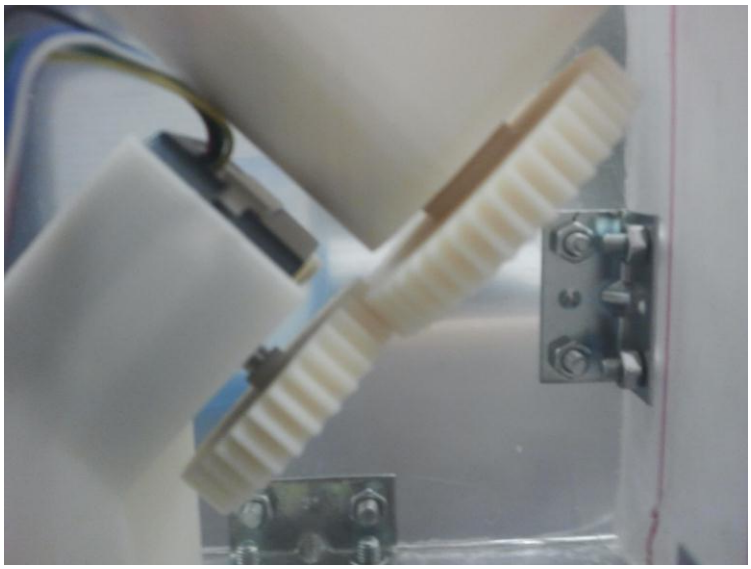


Figure 27. Successful mating of the gears.

A few more additional design changes were made after the completion of the second pill storage and dispensing mechanism. First more measures were taken to alleviate the problem of pill bridging that was discussed earlier. These changes are displayed in Figure 28.

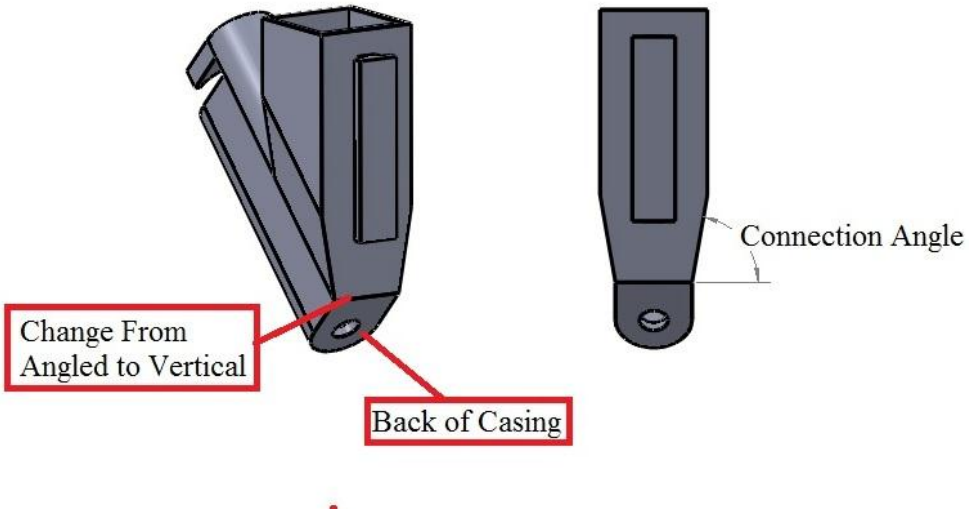



Figure 28. New Measures to Prevent Bridging

The connection angle was increased again to 80°. The main problem with increasing this connection angle in previous designs is that it would result in increasing the size of the back of the casing. Increasing the size of the back of the casing would result in pills resting on the back of the casing. This problem is shown in Figure 29. This problem can be solved by lowering the point where the back of the casing changes being from angled to vertical.

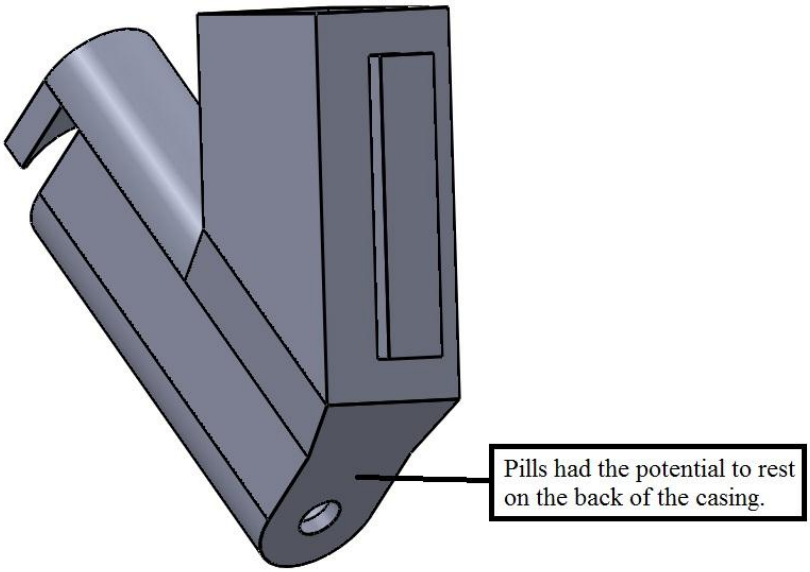



Figure 29. The flaw in previous connection designs

A new auger casing mechanism was designed to alleviate the bridging problem discussed previously. This design is shown in Figure 30. This design works by greatly decreasing the distance between the minor and major diameters. This means that none of the pills will try to rotate with the auger. Instead, they will ride on top of the auger shaft. This is the phenomenon that caused the larger disc shaped pills to be successfully dispensed by the first prototype and is shown in Figure 31.

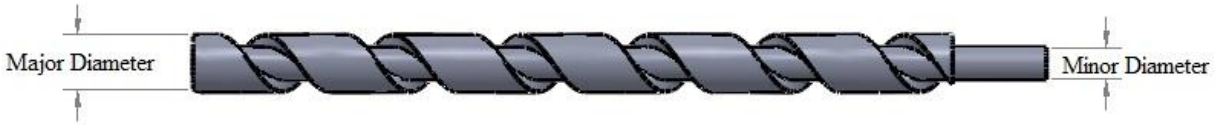



Figure 30. Auger design to prevent jamming in disc shaped pills.

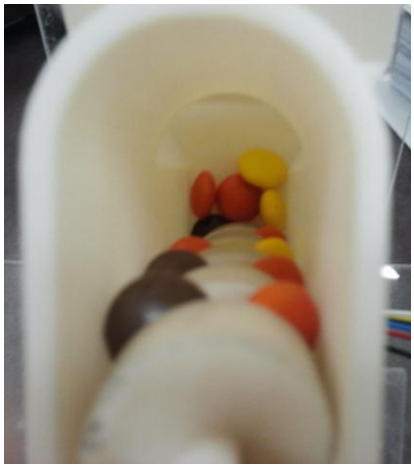


Figure 31. Pills riding on top of the auger shaft.

This design will be tested to see if it works with capsular pills. If it does, then all of the smaller pill storage and dispensing mechanisms will switch to this design. If not, then three different types of pill storage and dispensing mechanisms will need to implemented in the final build.

## Device Housing

Due to the difficulty with cutting straight edges on bulky pieces of Plexiglas with a band saw, it was deemed necessary to have the Plexiglas cut by a glass cutting company. It only cost ten dollars to cut the six panels that make up the device housing. Holes were drilled in each of the six panels using a mill as a drill press so that metal bracings and bolts could be used to fasten the panels as illustrated in Figure 31. The bracings were strategically placed so that they would not interfere with the placement of the dispensing mechanisms, while maintaining their function of adding structural strength.

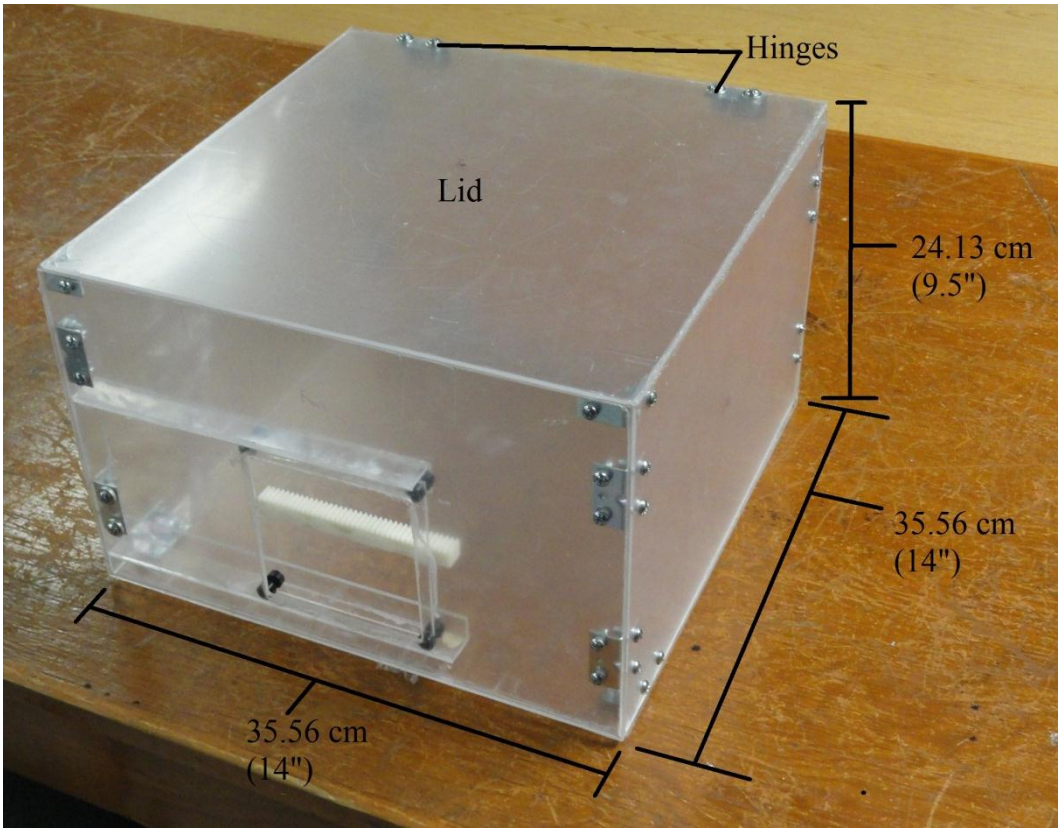



Figure 31: Isometric Image of Device and Dimensions.

The designed placement of the LCD screen and keypad were changed to the front of the device housing because it was tested to be convenient on a counter top much like a microwave. Also, it is preferable to attach electrical components to a stationary part. Both the keypad and the LCD screen will have wires attached to them. These wires would get in the way of the user when they raise the lid. The lid can be seen in both Figure 32.

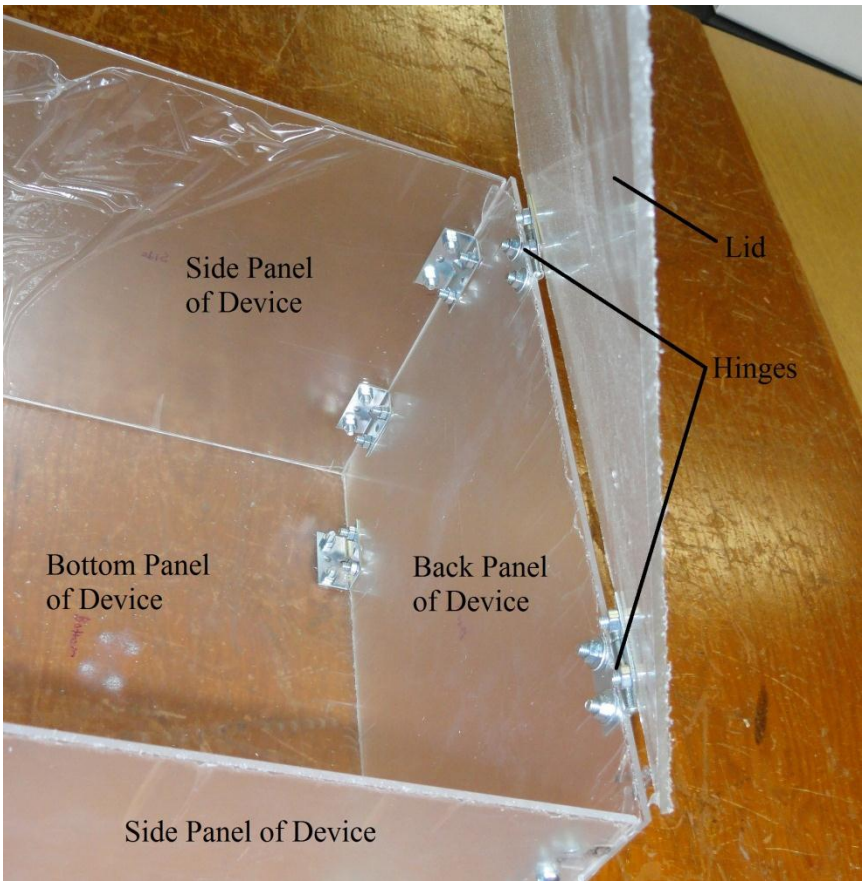



Figure 32: Hinged Lid Partially Opened.

Construction of Pill Retrieval Door:

Figure 33 shows the initial design of the pill retrieval door from last semester. The initial design used two smooth surfaced horizontal tracks that constrained the door on top and bottom, and motion was to occur in the form of sliding along the tracks. Dr. Miller pointed out that this design of the pill retrieval door would likely cause the door to bind due to the friction along the two tracks. Instead of redesigning the entire subsystem, the issue was resolved by adding wheels to the door to reduce friction. This solution saved time in our schedule because time was not wasted completely redesigning the door. Also, it saved money in our budget because the eight wheels were obtained from two small toy cars.

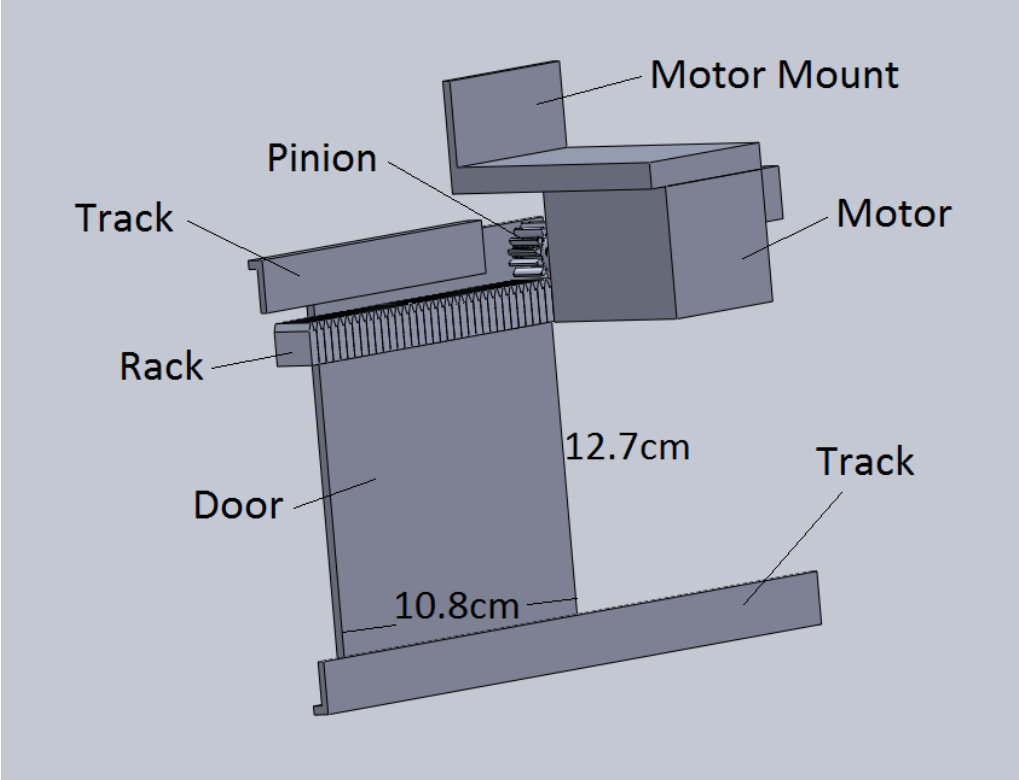



Figure 33: Initial Design of Automated Pill Retrieval Door and Rack and Pinion System

Construction of the pill retrieval door began by cutting the 10.16 cm x 10.16 cm (4 in x 4 in) doorway out of the front panel of the device housing as shown in Figure 34. The doorway was cut using a standard mill, and was a slow process because the Plexiglas cracked quickly when the mill's feed rate was too rapid. It ultimately took two passes to cut completely through the 0.3175 cm (1/8 in) thick Plexiglas. The door itself was cut using the same process as the doorway.

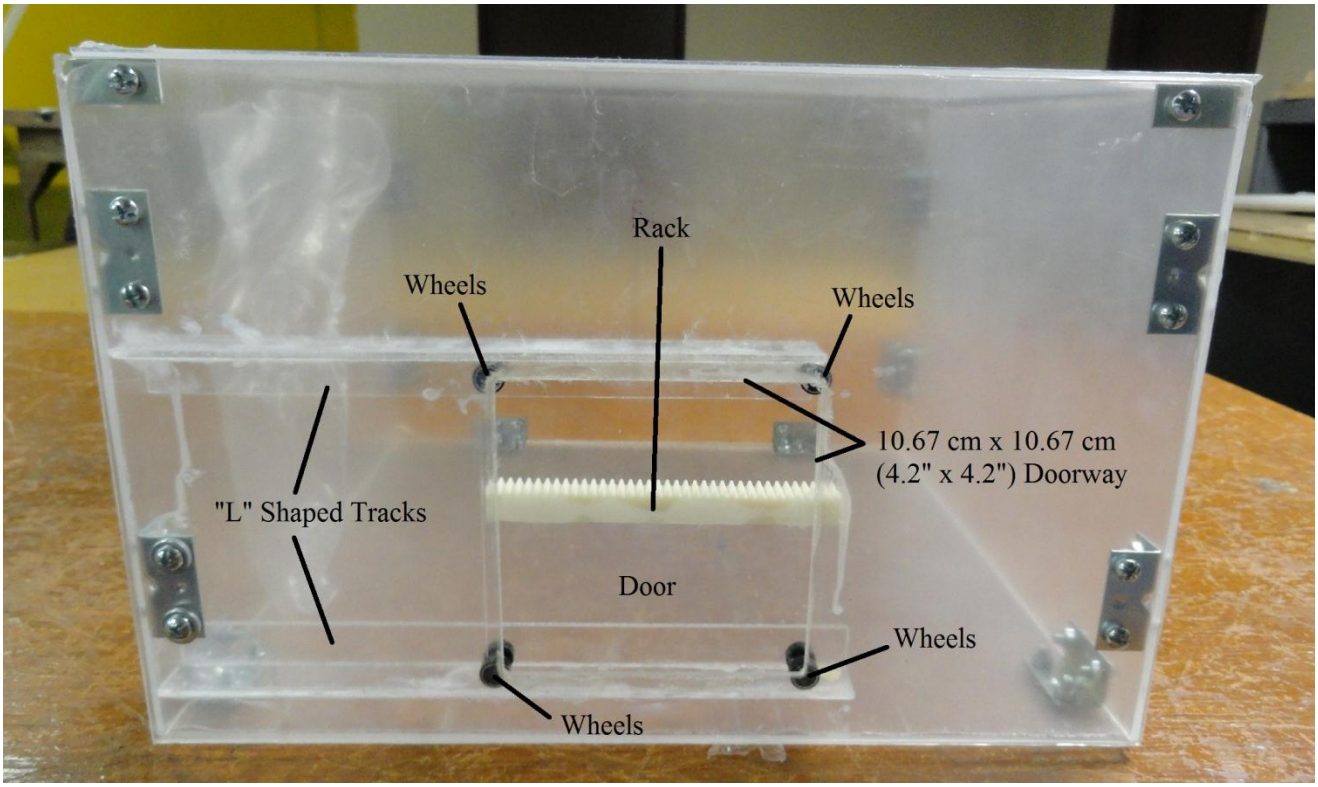



Figure 34: Pill Retrieval Door from a Front View of the Device (Motor Not Shown).

Thin strips of Plexiglas were cut with the band saw in order to construct the two tracks. The strips were glued together in an “L” shaped fashion, and these two “L” shaped tracks were glued directly to the device as shown in Figure 35.

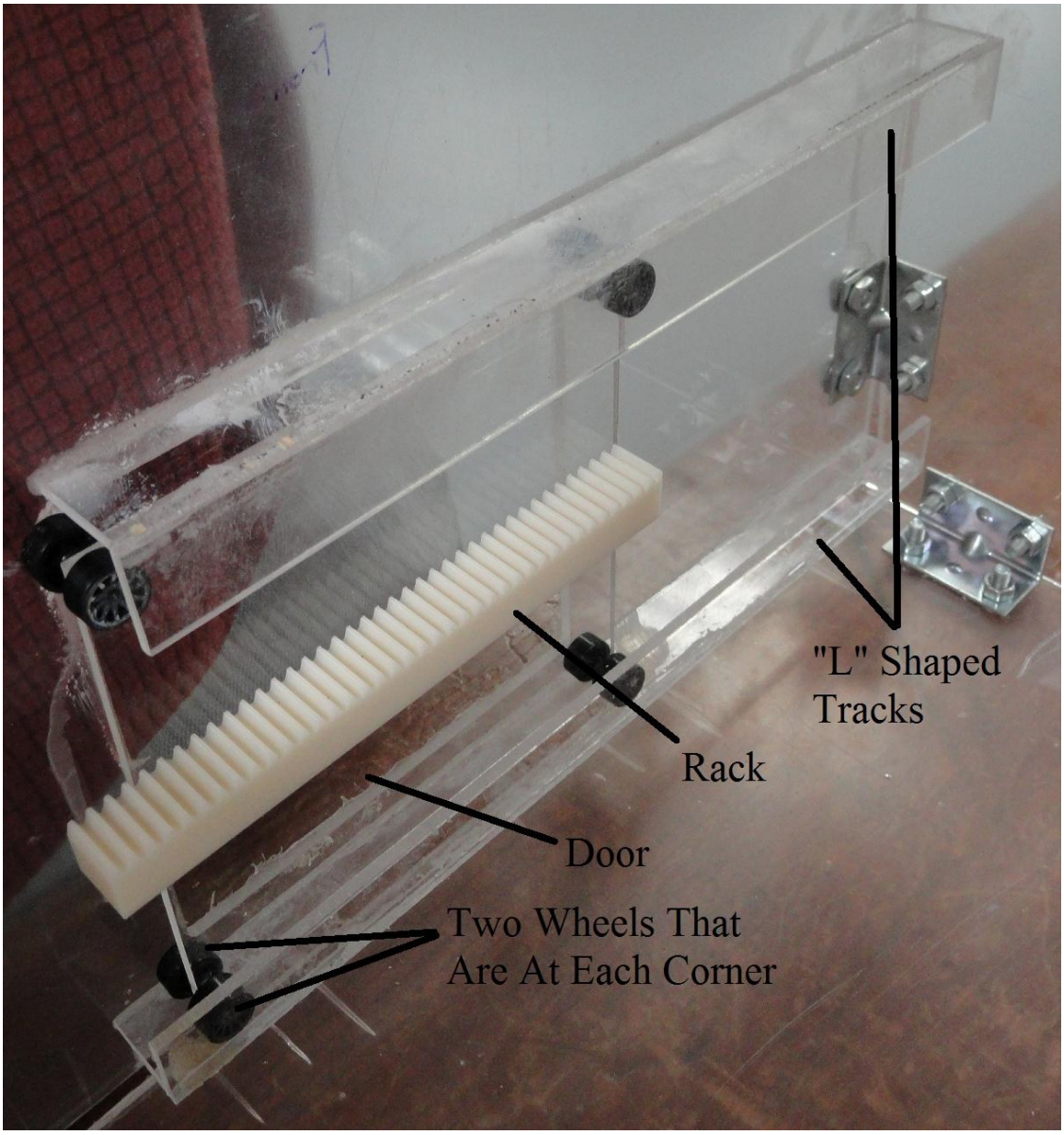



Figure 35: Pill Retrieval Door from a View Inside of the Device (Motor Not Shown).

The eight wheels in Figure 35 were connected to the door in four pairs by metal axles. Four small holes were drilled through the door, where each axle was inserted. The wheels are completely fixed to the axle, and door motion occurs through rotation of the axle within the door.

The stepper motor was bolted to the wall by a motor mount shown in Figure 36, and will be completely constrained. The motor mount was constructed from thin strips of Plexiglas and small metal braces being glued together. The pinion is fixed to the motors shaft and only has rotational freedom.

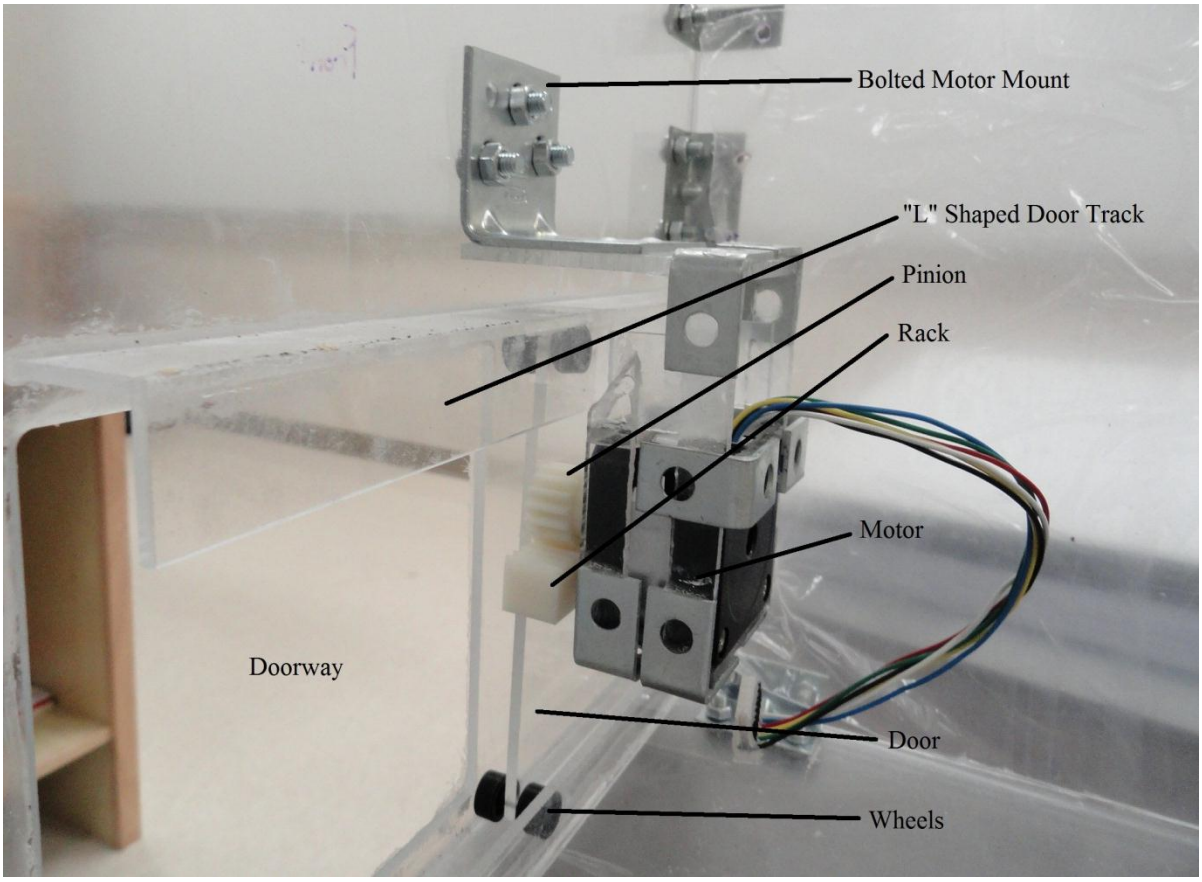



Figure 36: Pinion, Stepper Motor, and Motor Mount.

Design Change of the Pill Retrieval Area:

Through testing it was discovered that the force sensors were negatively affected by noise in the form of vibrations. The prototype would fail by mistaking noise for a pill dropping into the pill retrieval area. This failure only occurred when these vibrations were created by violently banging on the table the force sensors were resting on, and this form of vibrational noise was deemed to be worst case scenario. The solution to the problem was to suspend the pill retrieval area from the base of the device housing using string. The string is attached to a hole at each corner of the pill retrieval area, and acts as a damper by dampening much of the vibrations transferring from the device housing to the pill retrieval area. The string is fishing string specifically because it is strong, light weight, and cheap. There is potential that this problem could have been solved with digital filtering; however, the force sensors are not good at measuring the actual force placed on the sensor. They are only good at detecting spikes in force. This makes it difficult to distinguish between noise of a certain magnitude and the dropping of a pill. This mechanical filtering method is an easy, foolproof way of solving the problem.

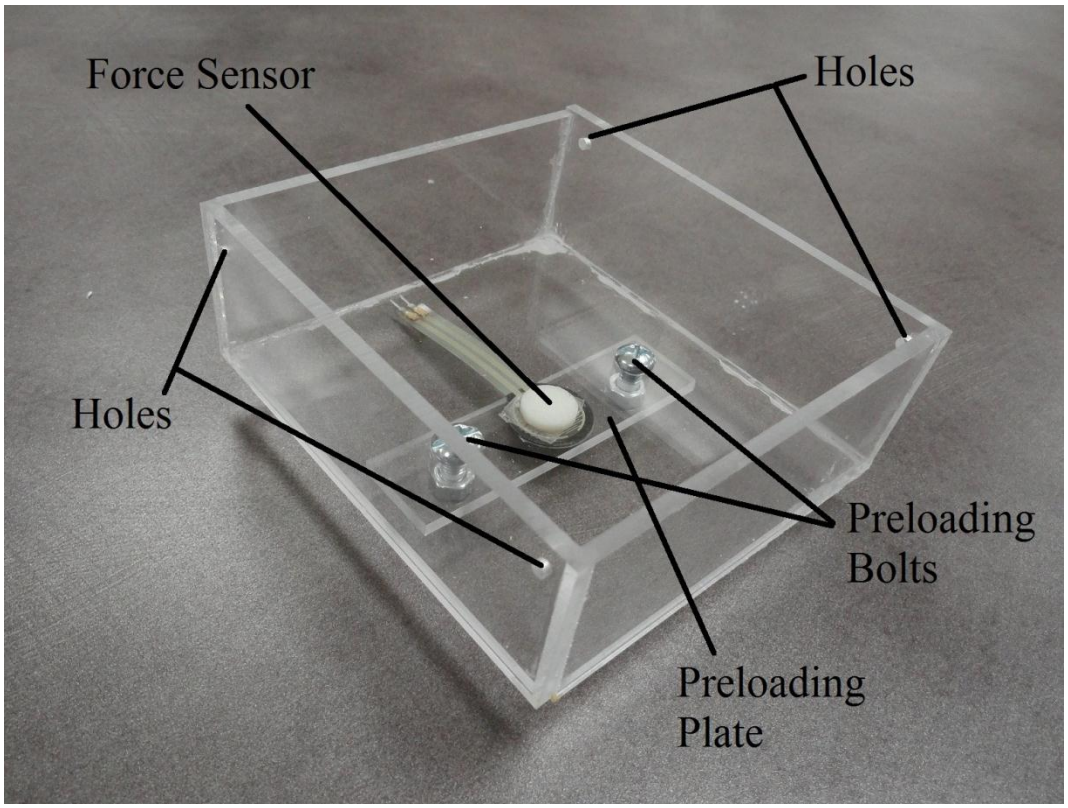



Figure 37: Pill Retrieval Area with Preloaded Force Sensor

The four holes that will suspend the pill retrieval area are shown in Figure 37, and correspond to the four holes at the top of the "U" shaped supports in Figure 38. The preloading plate and bolts provide the necessary preload for the force sensor to detect pills dropping into the tray. All of the panels that compose the pill retrieval area are Plexiglas, and were cut using a mill. The pill retrieval area is glued together in accordance with the dimensions shown in Figure 39. The final design of the pill retrieval area has been constructed and integrated into the device displayed in Figure 40, and it operated successfully in tests where worst case scenario vibrations where created within the device.

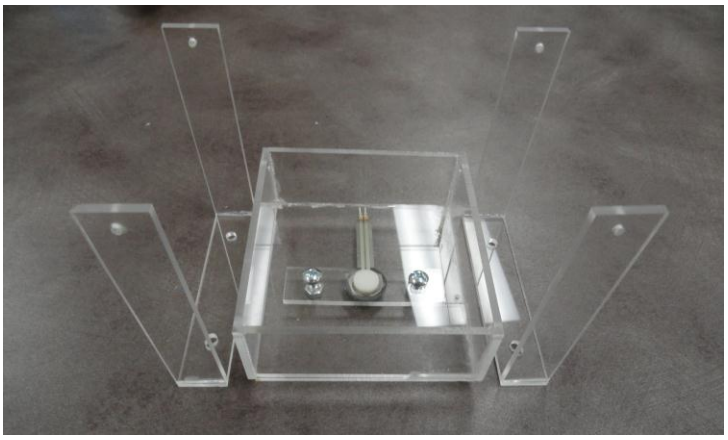


Figure 38. U shaped supports.

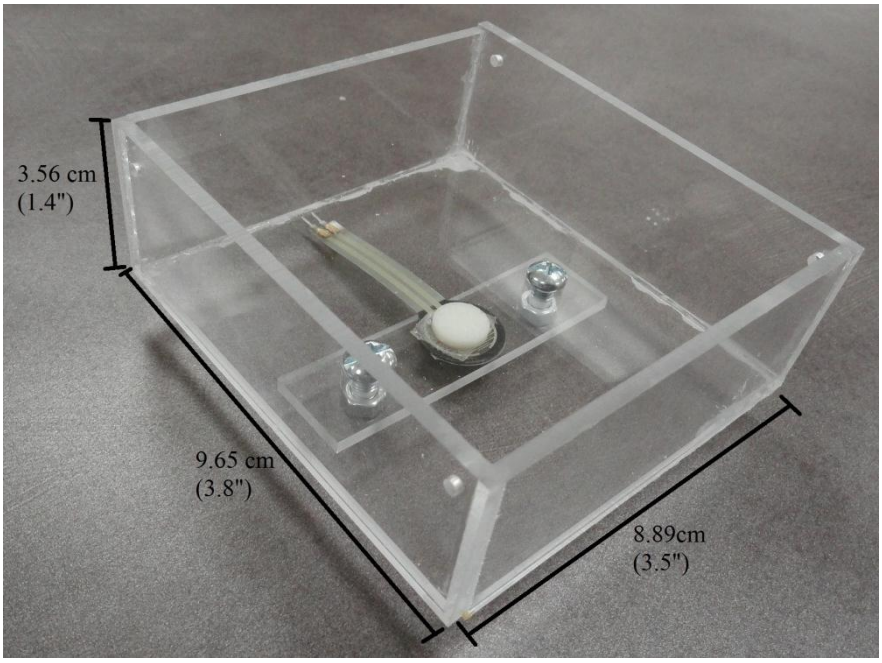



Figure 39: Dimensions of Pill Retrieval Area

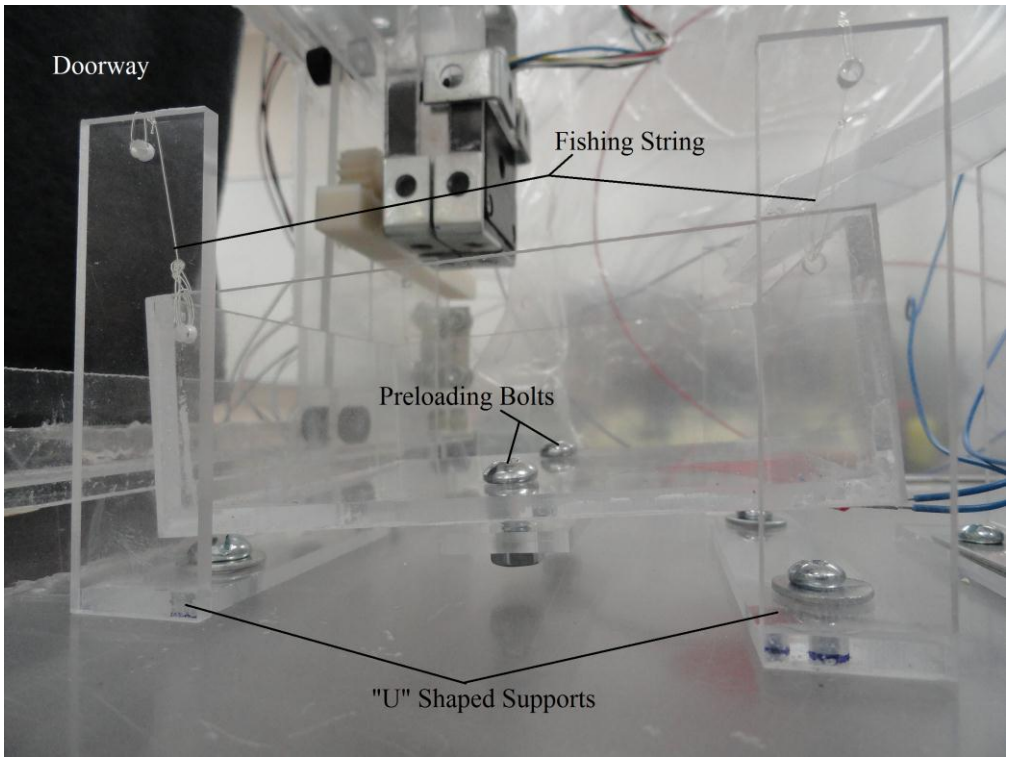



Figure 40: Pill Retrieval Tray Suspended within the Device

Slide:

Construction of the slide is underway. The colored portions of the slide in Figure 41 have been milled out of Plexiglas. The final dimensions of the slide's width and height will be known when the dispensing mechanisms are finalized, so slide construction is currently halted until these values are known. The slide itself will consist completely of Plexiglas, and will be glued together to form its shape. The support structure of the slide will consist of Plexiglas and metal braces, and is not shown. Construction of the support structure is also in progress.

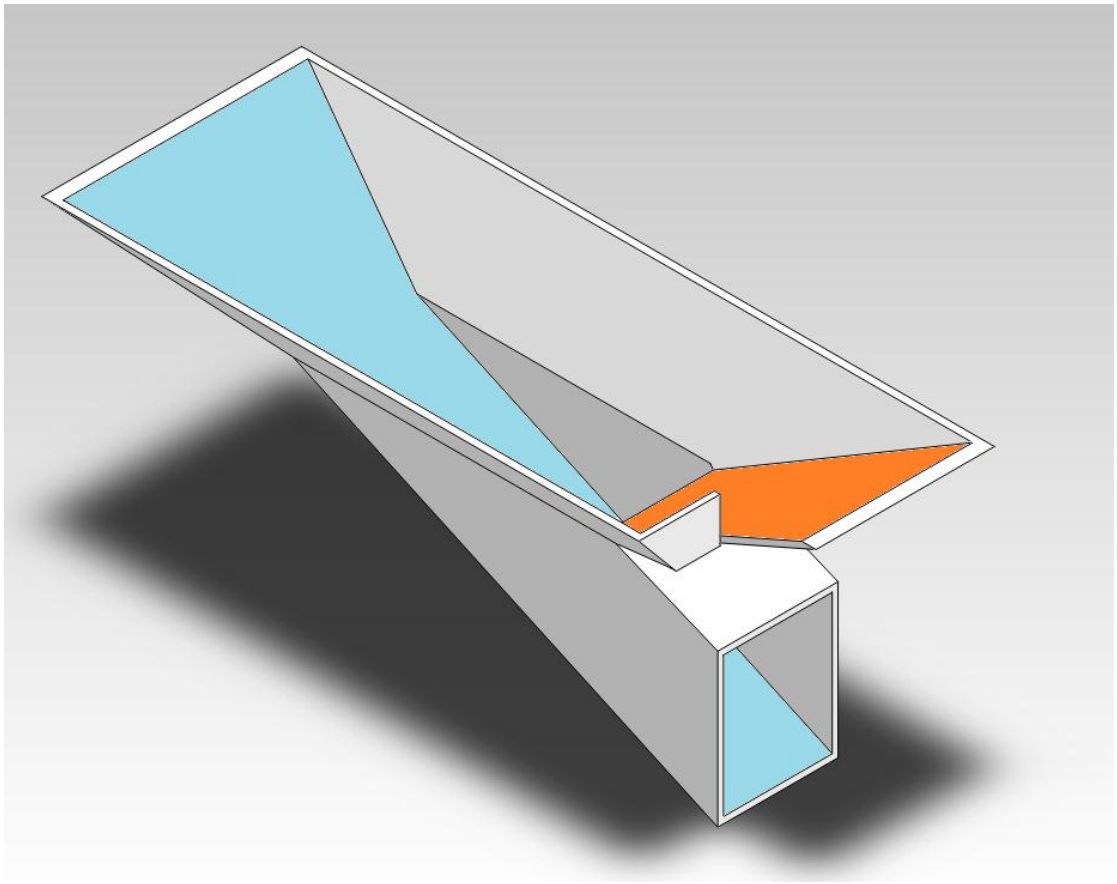


Figure 41: Slide Design and Current Progress

## Power Supply

Overview

The purpose of the power supply is to receive power from the wall outlet to power the device. It will convert the voltage from AC to a lower DC voltage to supply the power needed for the electrical components. One of the requirements stated previously is that the power supply should have back up batteries that will keep the device running for at least one week.

Initial Design

The initial design for the power supply was to gather the components-the transformer, resistors, capacitors, regulators and build it. It had been simulated to work in Multisim to power all of the subsystems as necessary, but due to heavier components than anticipated, a power supply was purchased to meet the device's weight requirements.

New Design and Progress

The power supply purchased regulates voltage to use 12 V at 0 to 0.5A, 5 V at 0 to 2A, and 3.3 V at 0.5 to 4A to power the different components the device needs to operate. Note that the motors are now operating at 12V as opposed to 15V in the initial design; there is also only one sensor being used, and an additional motor for the door gate. See Appendix J. These components are the following:

- 10 Stepper Motors: 12 VDC at 300 mA
- Alarm: 5V at 250mA
- Microprocessor: 5V at 29-45 mA
- Keypad: 5 V at 5 mA
- LCD Screen: 5V at 300mA
- 1 Force Sensor: 5V at 4.5-80mA
- Wi-Fi Transceiver Module: 3.3V at 150mA
- RFID chip: 5V at 100mA

Power calculations had to be recalculated for each component to make sure the power supply can supply enough power to all of the components.

$$P = V * I$$

For the 12V: $P_{12} = (12V * 300mA * 10) = 36\ W$

For the 5V:

$$P_5 = (5V * 250mA + 5V * 300mA + 5V * 80mA + 5V * 100mA + 5V * 45mA) = 3.875\ W$$

For the 3.3V: $P_{3.3} = (3.3V * 150mA) = 0.50\ W$

The total power needed for the device to function at its worst case (motors being used at 12V) is 40.38 W. The power supply can give up to 55 W which is more than what is needed.

Construction and testing

The construction still needed for the power supply is to solder wires that will go to the wall outlet and from each voltage output to the subsystems. Each subsystem was tested before being integrated to the power supply.

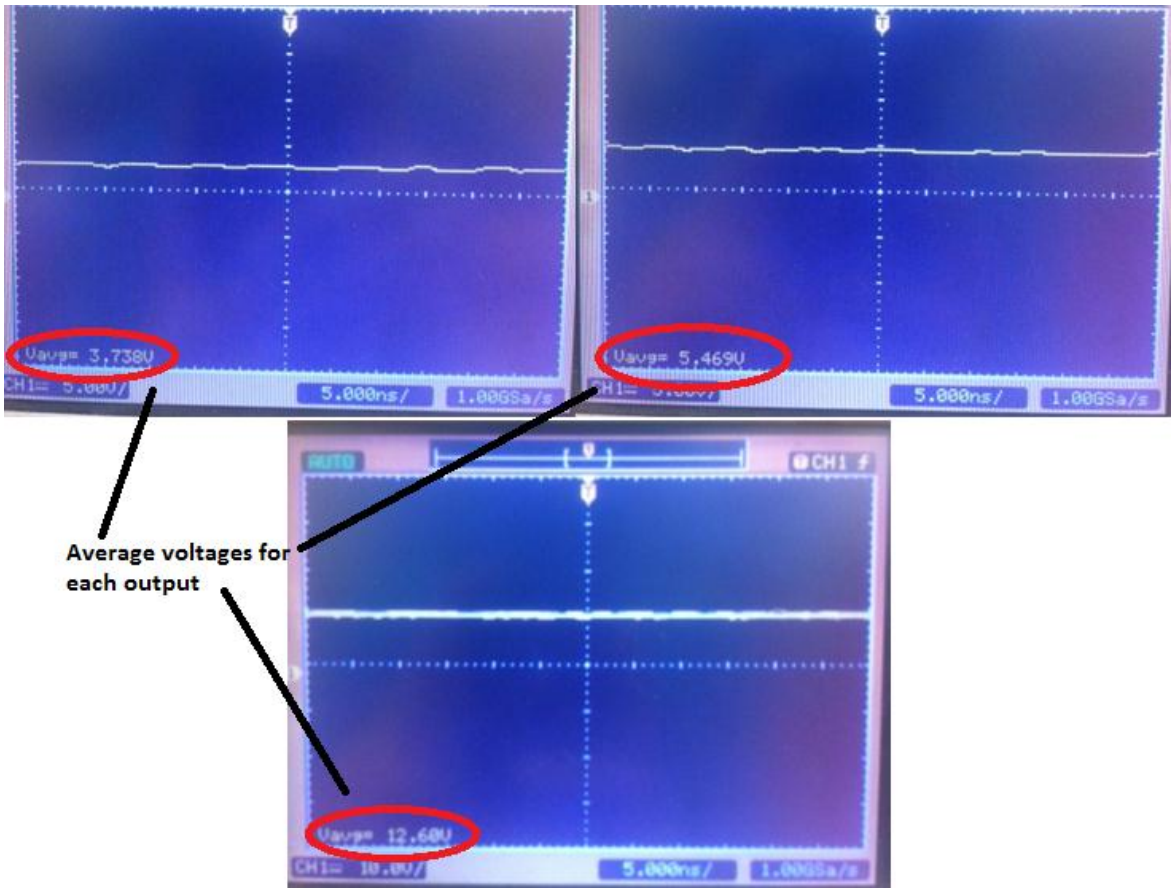
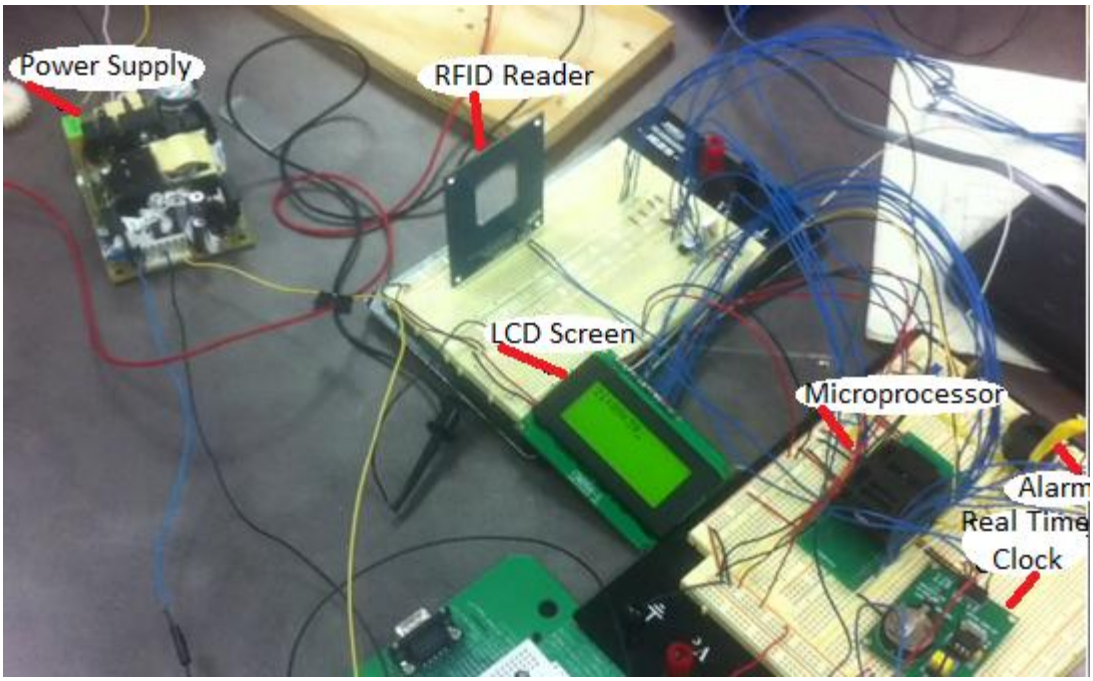



Figure 42. DC Voltage Outputs from Power Supply

The DC voltage outputs from the power supply shown in Figure 42 are very steady as time elapsed. For the 3.3V, a voltage average of 3.738V was measured, for the 5V, a voltage average of 5.469V was measured, and for the 12V, a voltage average of 12.60V was measured. The power supply was tested individually with each subsystem and with several subsystems at the same time, powering all of them successfully.




Figurer 43. Power Supply with Subsystems

Figure 43 shows the power supply connected to some of the subsystems, the RFID reader, the LCD screen, the microprocessor, the alarm, and the real time clock when they were integrated to test their functions. Other subsystems that were integrated and not shown in the picture were the motor controller circuit, the sensor in the pill retrieval area, and the keypad.

Battery Backup Design and Progress

One of the requirements for the battery is that the device should work for at least one week with a backup power system. The power calculations can then be multiplied for the device dispensing nine pills, three times a day, for an entire week. Another requirement related to the battery is the device's weight.

Initial Design

The initial design of the battery was to have four 9V disposable alkaline batteries with two parallel pairs connected in series, supplying power after a power outage. Power from the batteries was at 18V so the motors could run with 15V.

New Design Construction and Testing

Since the motors are still the components that require the most power, 36 W, running at 12 V, we do not need 18V to power the motors. Data was taken to show the relationship between voltage and torque. When the motors are using 9V, it is still a good torque and the motors function well. Therefore, when the device is battery powered, the motors will be running at 9V. This means there will only be two 9V batteries in parallel that still supply all of the power needed.

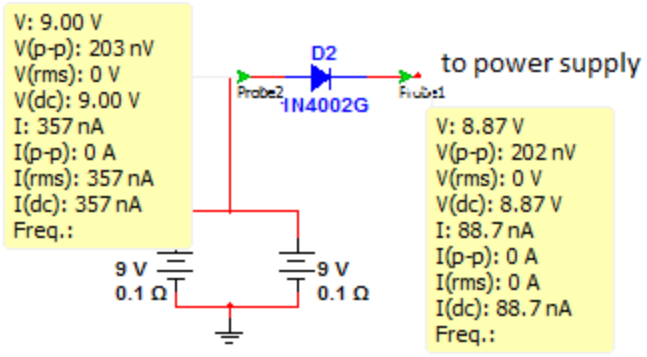



Figure 44. Batteries' Schematic

Figure 44 shows the battery schematic in Multisim. Figure 45 shows the batteries' circuit schematic with the components and the output for each regulator, 5V and 3.3V. They both show a steady signal through time.

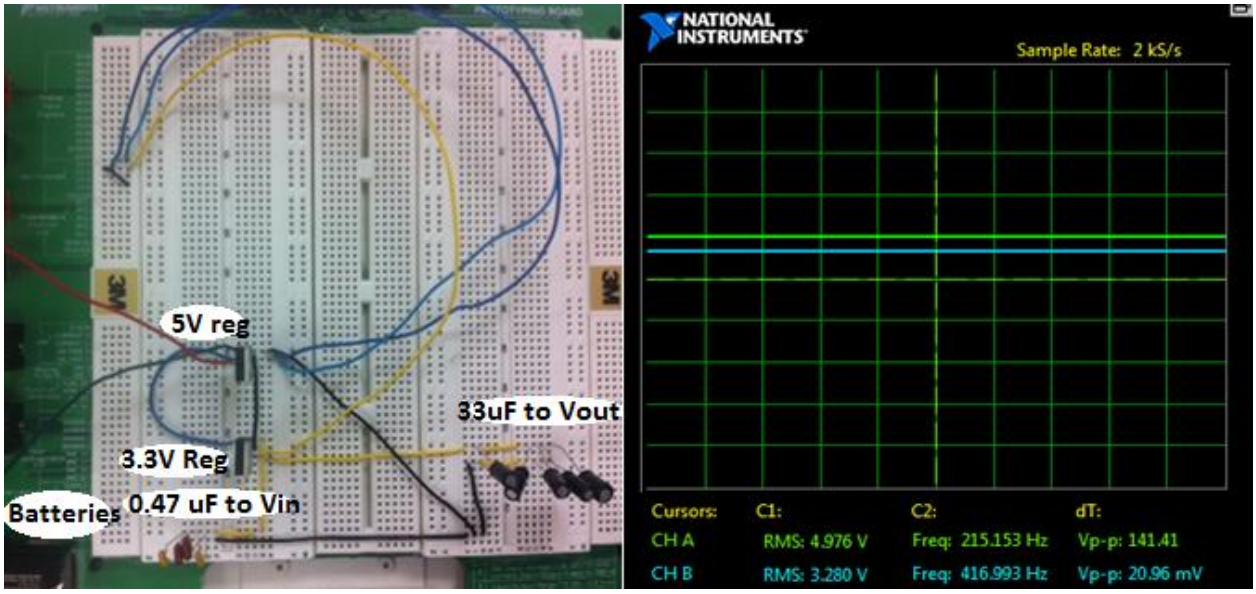

5V reg
33uF to Vout
3.3V Reg
Batteries
0.47 uF to Vin
NATIONAL INSTRUMENTS
Sample Rate: 2 kS/s
Cursors: C1: C2: dT:
CH A RMS: 4.976 V Freq: 215.153 Hz Vp-p: 141.41
CH B RMS: 3.280 V Freq: 416.993 Hz Vp-p: 20.96 mV

Figure 45. Batteries Circuit Output Voltages

Again, power calculations were recalculated for the battery powered components. The components are taken into account to operate at their maximum – nine pills for seven days for three times a day. The components that most need power during this time are:

- Alarm:

$$3beeps\ (200ms) = 0.6\left(\frac{2\ times}{1\ min}\right)(30min) = 36\ s(250mA) * \frac{1min}{60\ s} = 150\ mA \cdot min$$

- Sensor: $1min * 80mA = 80\ mA \cdot min$
- Motors: $300mA * \frac{1min}{1\ motor} * 10motors = 2700\ mA \cdot min$
- RFID: $100mA * 1min = 100mA \cdot min$

$$\Sigma(\text{Alarm} + \text{Sensors} + \text{Motors} + \text{RFID}) = 3330\ mA \cdot min\ * \frac{1hr}{60min} * \frac{1A}{1000mA}$$
$$= 0.0555A \cdot h$$

$$0.0555A \cdot hr * 7days * \frac{3\ times}{1day} = 1.166A \cdot h$$

Battery Indicator

Initial Design

The initial design for the battery indicator was to have the microprocessor read the voltages of the batteries and indicate if the batteries were low. Since the batteries will only be used in case of a power outage, the batteries could be drained by just checking if there is enough voltage without being used.

New Design

The battery indicator circuit will be attached to the battery circuit in the power supply circuit with a switch that if it is turned on and there is enough voltage to operate, an LED will turn on; similarly, if the switch is on and there is not enough voltage, no LED will turn on. The voltage considered high enough for the LED to turn on is 7.7V or higher.

Figure 46 shows this scenario of having the switch off on the left side, and the switch on with the LED on, on the right side.

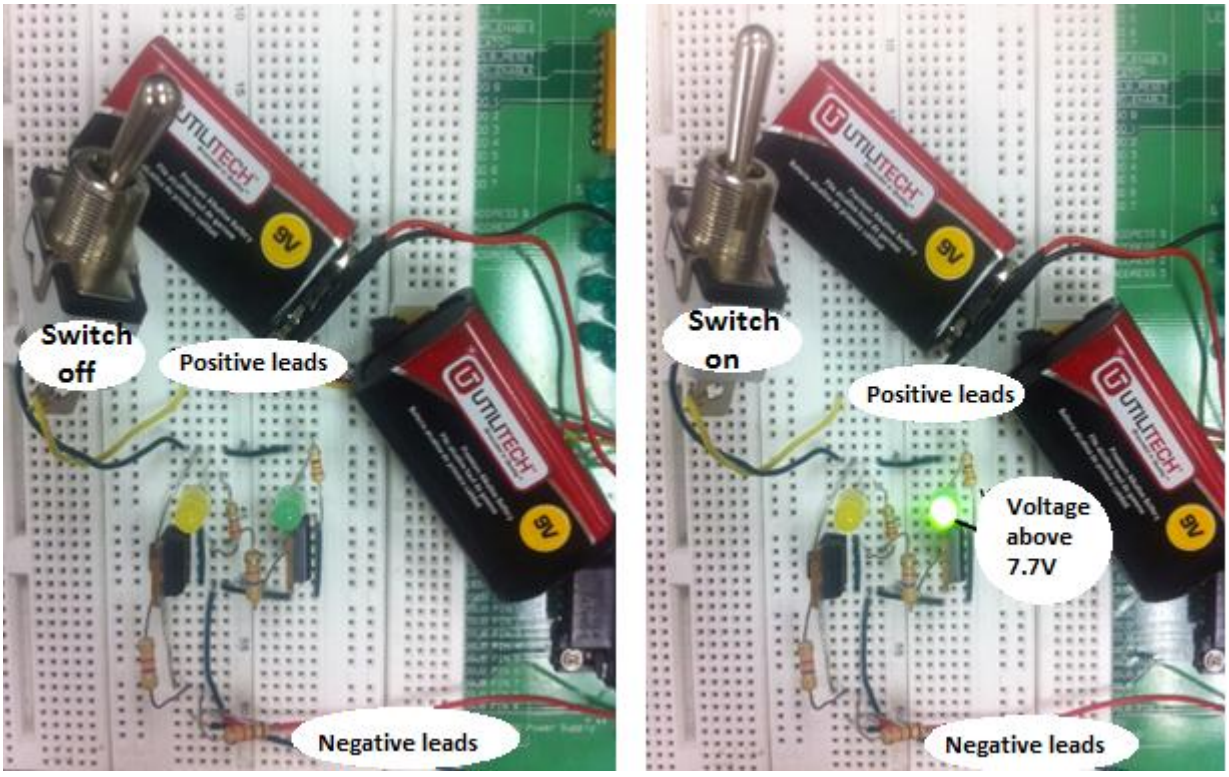



Figure 46. Battery indicator circuit with the switch off and on

## Control System

Overview:

The overall purpose of this system is to control all of the other components of the device using electrical signals so that the device operates according to the specified requirements. More specifically, this system makes sure that the pills are dispensed when they are supposed to be, that the right amount of pills are dispensed, that the patient receives the pills, and that the caretaker is informed if anything is wrong. This system communicates with most of the other systems to achieve this. All of the information about the medication in the device; such as how many pills there are in each bin, when each pill should be dispensed and how many of each pill should be dispensed, is all stored in the control system.

Microprocessor:

Currently the processor has been put onto a breadboard using a 64 pin socket that has been soldered onto a PCB with a header for each pin. Programming has been done using ICSP (In Circuit Serial Programming) using the MP Lab equipment.

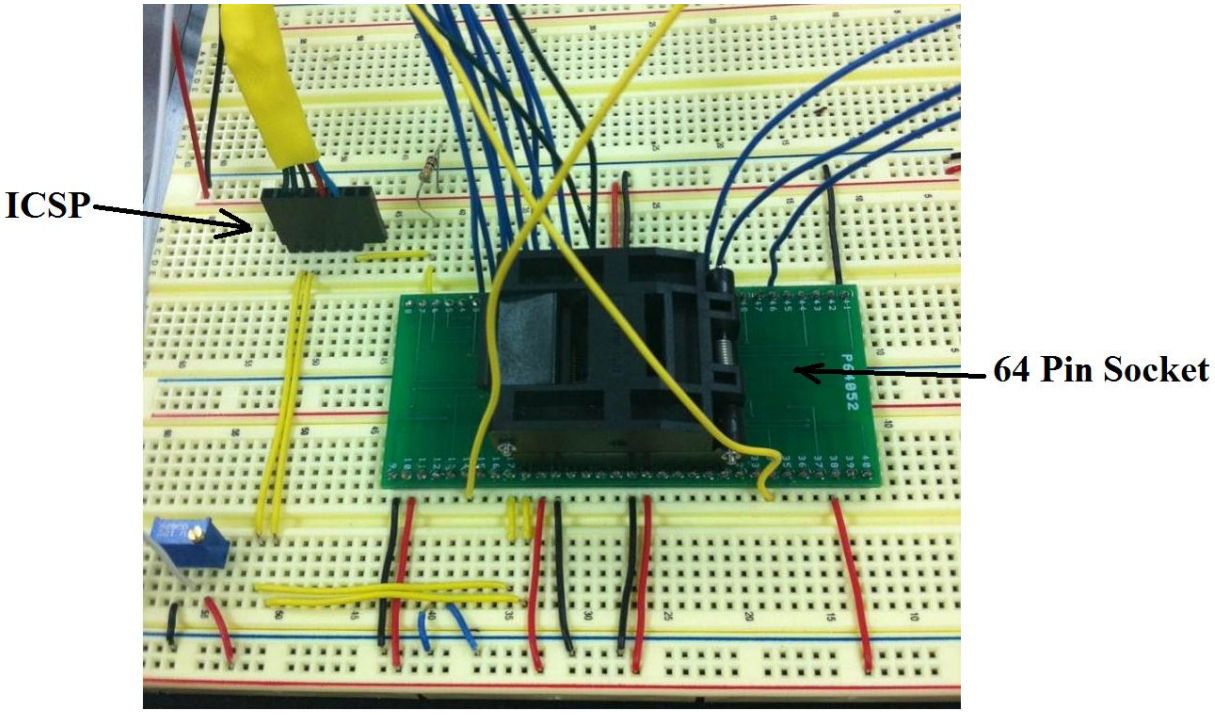



Figure 47: This shows the socket with the breadboard and a few components connected.

Currently all of the programming done has been for each component individually. The keypad has been programmed to output to the LCD as required. A program has also been written to receive data from the RFID reader using the UART module built into the processor. Once a card is scanned the processor outputs a confirmation message to the LCD screen. A program has been written for the most recent prototype that will turn a single motor and poll the A/D reading from the sensor until a pill drop is detected. The motor controller circuit has also been tested and a program has been written that can successfully turn multiple motors, one at a time, and in different directions. The functionality of setting the time and getting the time for the real-time clock has been programmed, also the programming required to turn on and off the alarm has been finished. The Wi-Fi transceiver is the only component that the programming is not finished for. Once this is done, the final system program can be completed.

The processor will first be soldered to a SchmartBoard and then connected to a professional PCB. A picture of the SchmartBoard can be seen below. The PCB is designed to have through holes that match the outer holes on the SchmartBoard. Double sided male connectors will be used to attach the two boards.

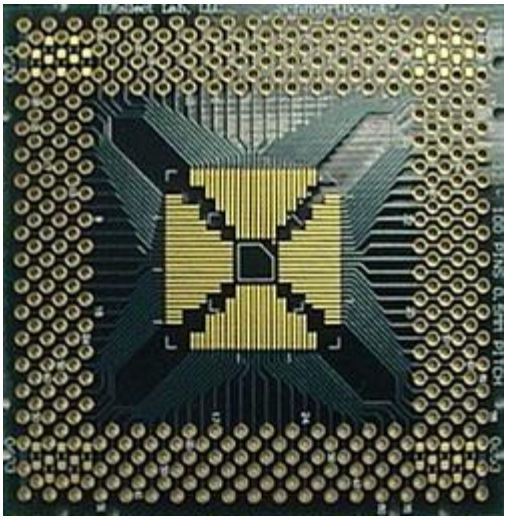


Figure 48: This is a picture of the SchmartBoard that the processor will be soldered to

The following design includes connections for everything that will be interfaced with the microprocessor. It also contains the circuitry for the motor controller, the keypad, the alarm, and the LCD screen. The orange box shows the outline of where the SchmartBoard will be connected. This design is 10.2 x 10.2 cm (4 x 4 inches). This board has been ordered from www.4pcb.com.

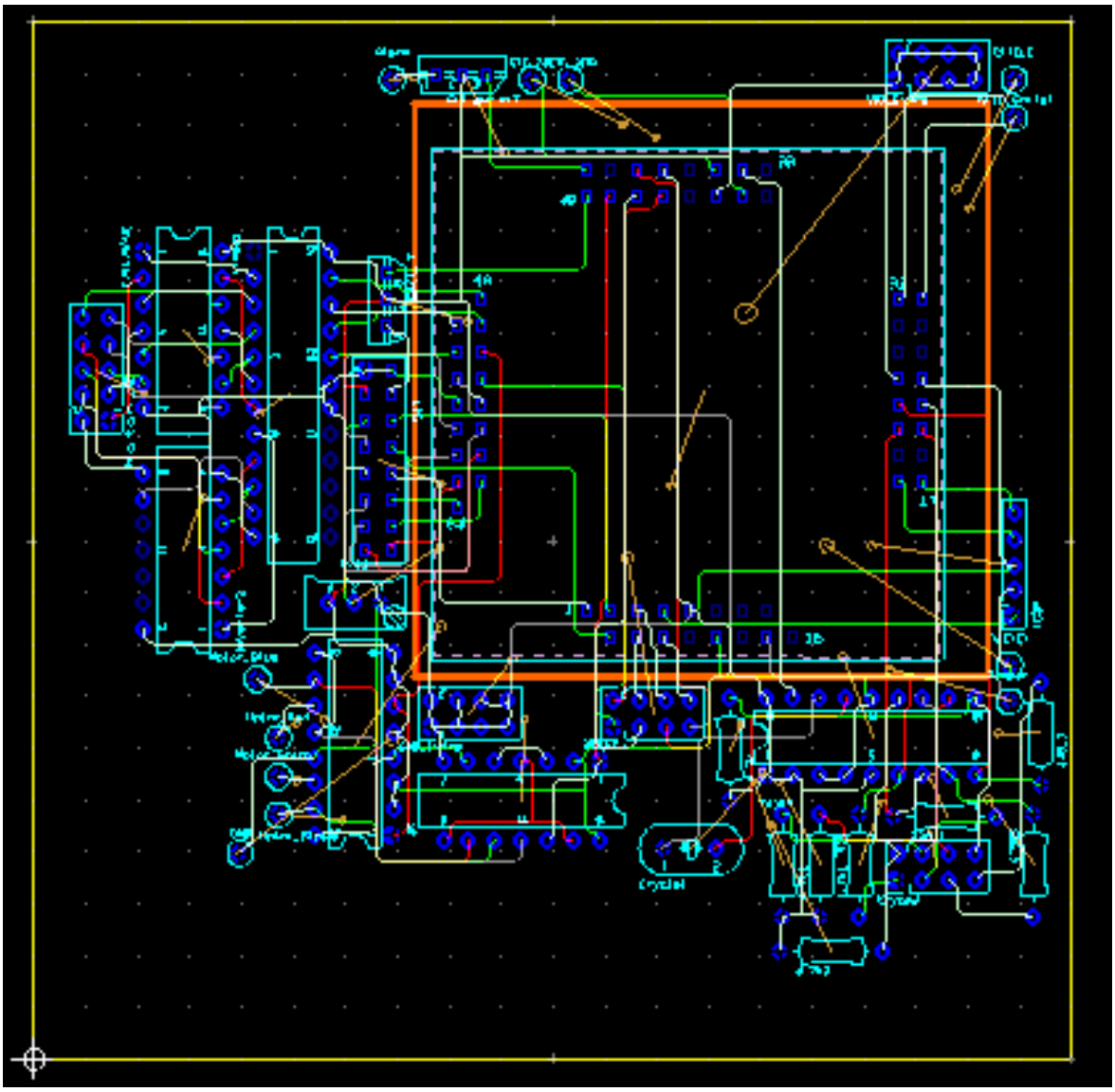


Figure 49: This shows the initial design for the control subsystem done in ultiboard

Wi-Fi Transceiver Module:

This module has taken some time to prepare for testing. It does not have pins that allow it to be inserted directly into a breadboard so a separate circuit board was required to be designed and printed. Here is the first design that was made in ultiboard:

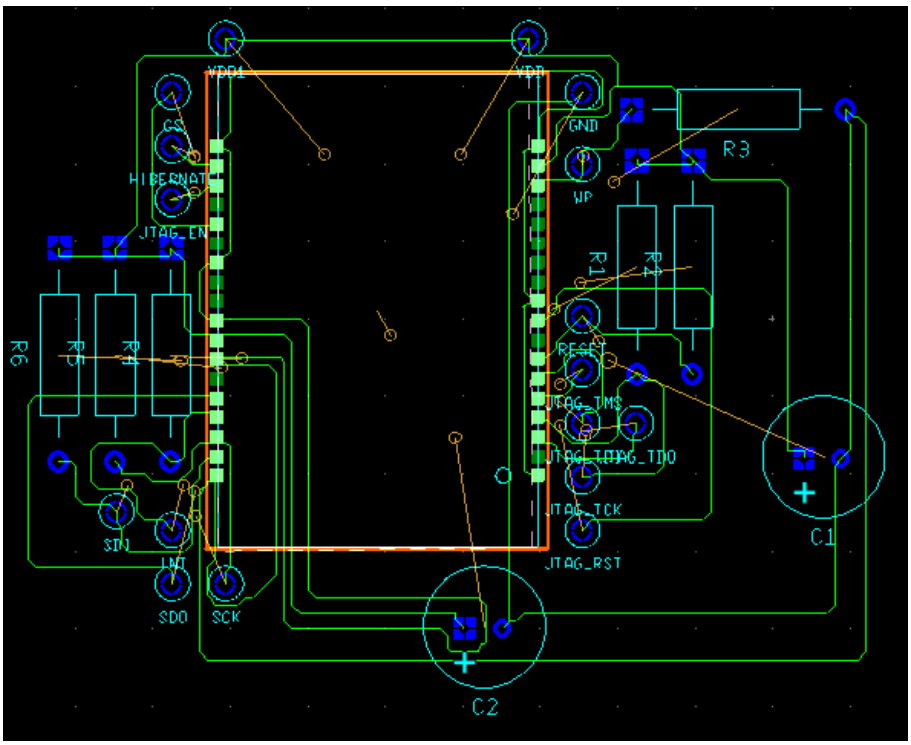



Figure 50: A PCB design for the Wi-Fi Transceiver.

The component has finger pins that need to be soldered to the square pads shown in the PCB design. After printing the board however, it became apparent that it is nearly impossible to solder the pins to the board by hand. Instead, the use of solder paste and the reflow oven was needed to solder the component to the board. This worked very well and all pins formed a solid connection with the pads; however, a connection was formed directly between VDD and GND. This obviously was a major problem. This was probably caused by the traces that ran underneath the component. This problem was originally ignored because it was thought that the resist left on the traces would prevent this from happening but the reflow oven burned off all of the resist left on the board. The board was redesigned so that any of the traces running under the component would not cause an unwanted connection.

Figure 51: This shows the Wi-Fi transceiver component soldered onto the first PCB that had the problems with the unwanted connections

The PCB design for the transceiver was adjusted so that there were no unwanted connections due to traces running under the component. The traces were also increased in size to make sure that all of the connections were good.

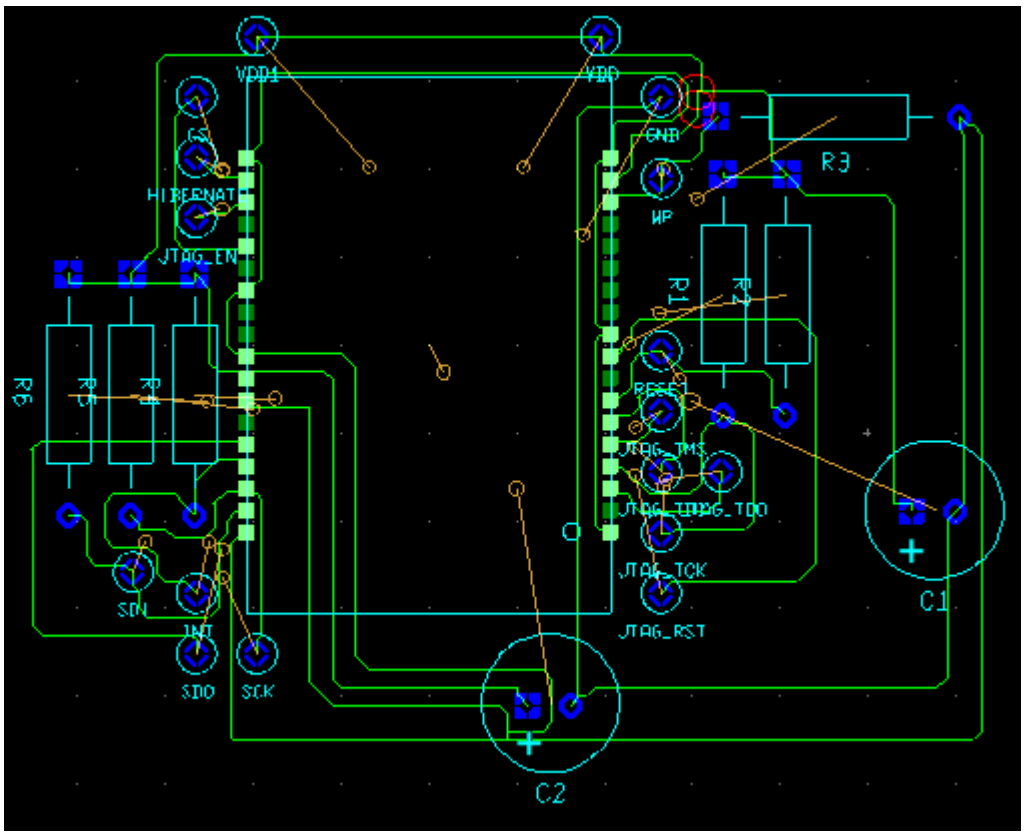



Figure 52: This shows the second design for the Wi-Fi transceiver circuit

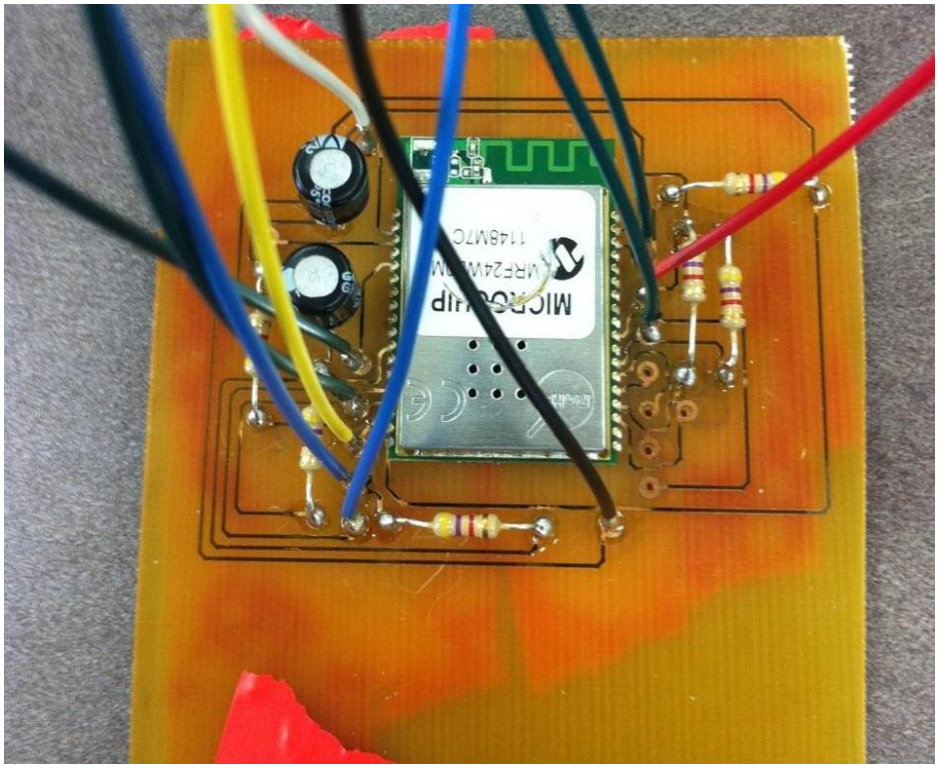


Figure 53: This shows the Wi-Fi transceiver component soldered onto the new PCB

This time all of the connections were correctly made and the rest of the components were soldered into place. At this point there still has not been any programming done for this component. Unfortunately, none of the groups in the past have used this component before, so there is no documentation from past students for this component. The TCP/IP libraries have been downloaded and installed. Unfortunately this is a very large file with many header and c files. Also, all of the demos included with this library are intended to be used with one of Microchip's pre-built development boards. All of this code will have to be sorted through to get the functionality required for the device, and a hardware profile needs to be created that matches the processor being used instead of what is used with the pre-built development boards.

Real Time Clock:

The code necessary for programming a time and retrieving the time from the real time clock has been completed. Now a time can be set to the clock and stored even after power to the board has been removed because the clock's separate backup battery maintains the value stored in the clock. The program written can set the time, and retrieve the time and output the retrieved time to the LCD screen as shown below. There will be no more work required for programming this component. The code for this can be seen in appendix I.

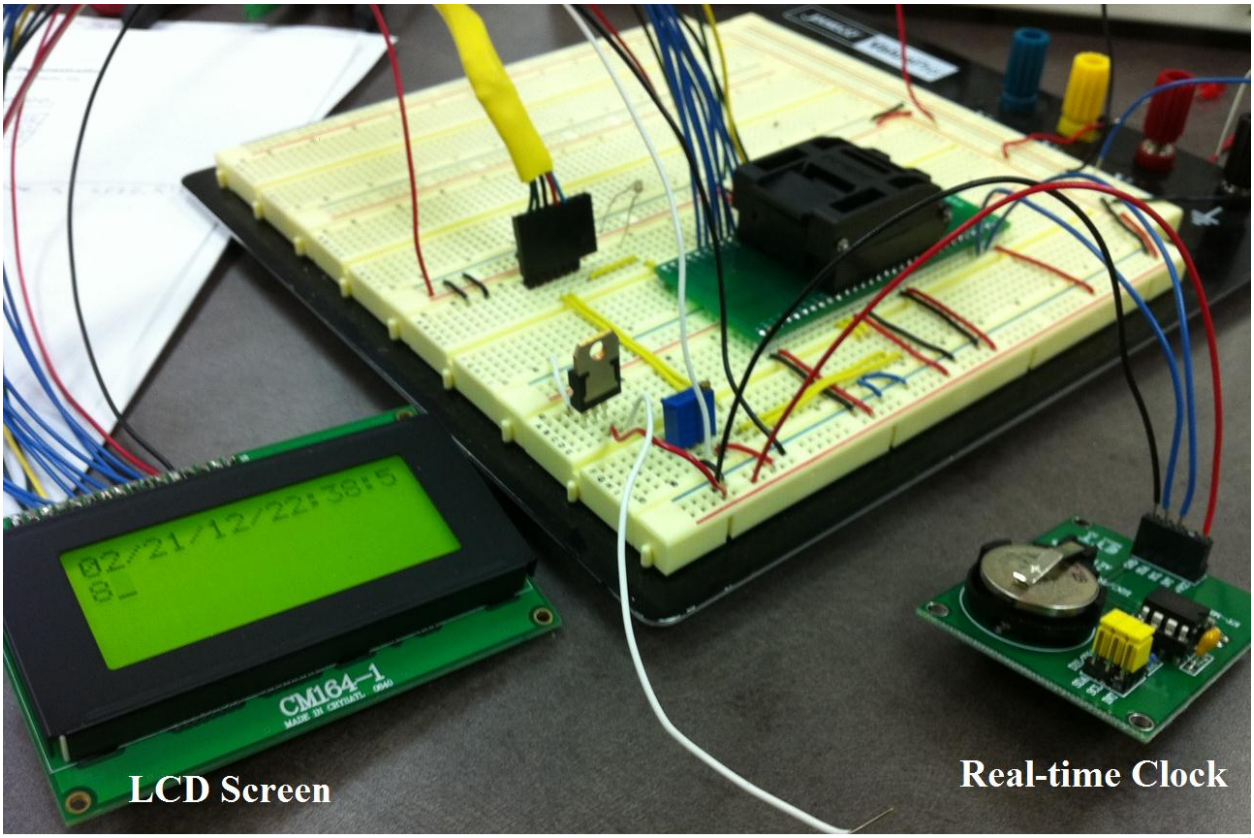



Figure 54: This shows the real time clock circuit on the right connected to the processor in the middle with its output on the LCD screen to the left.

Motor Controller Circuit:

This circuit has been partially breadboarded to test that it will work. A program was written that successfully controlled multiple motors, one at a time. The processor can also change the direction the motors turn using a single output. A program was also written to test this circuit with the door motor. It successfully opened the door, paused and fully closed the door using this circuit.

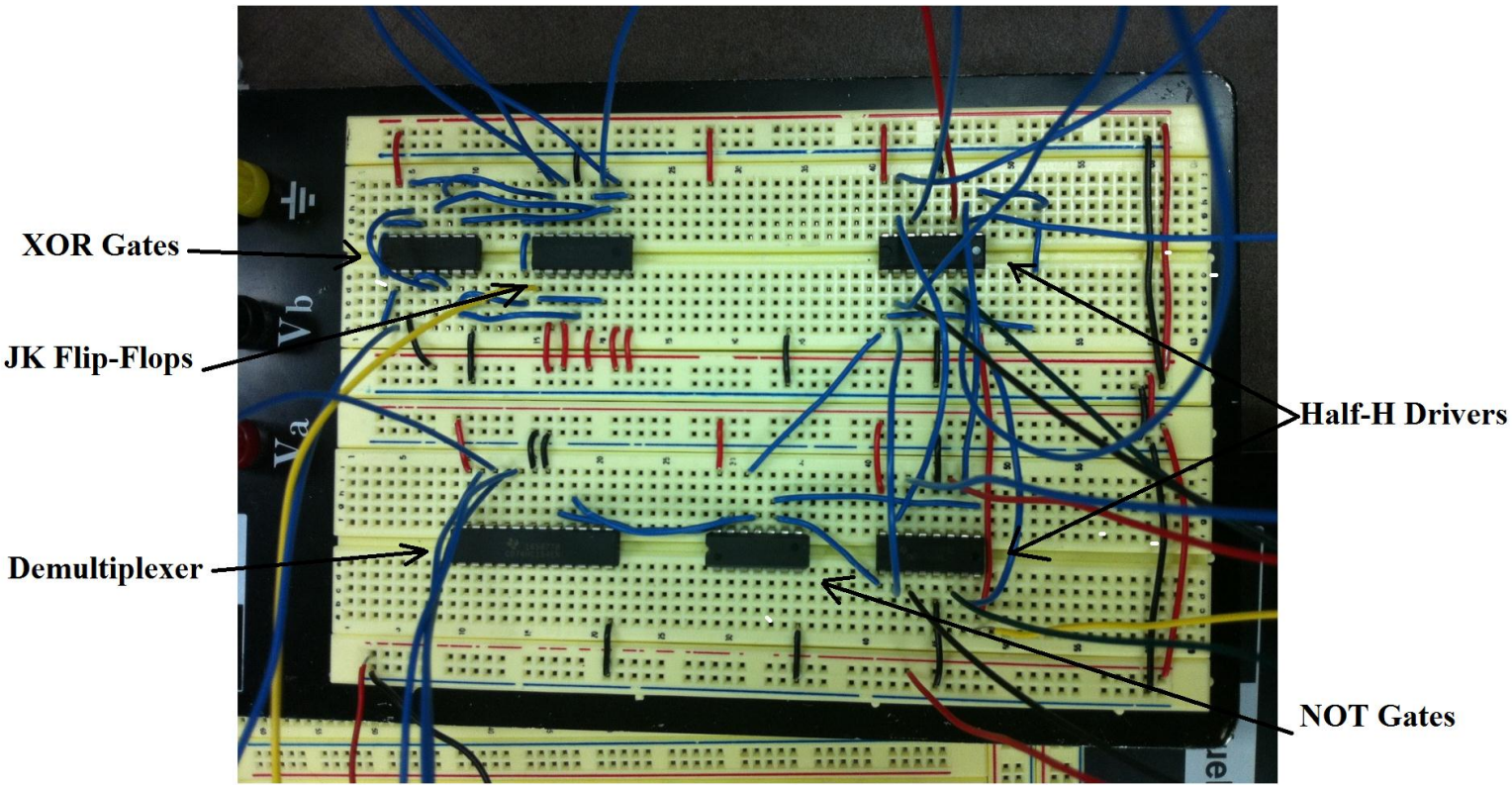



Figure 55: This shows the demultiplexer (bottom left), driver logic (top left), and motor driver chips (right).

Each motor will have one of the 754410 half-h driver ICs. In order to do this, 10 small PCBs will be used to hold each motor driver. Below is a picture of one of the circuits that has been made for this. It receives four signals for controlling the motors, an enable signal from the demultiplexer, +5 V, +12 V and GND. The inputs for power, ground, and the motor signals all have an extra hole so that these can be output from each chip to the next. This will reduce the amount of wires needed for the motors.

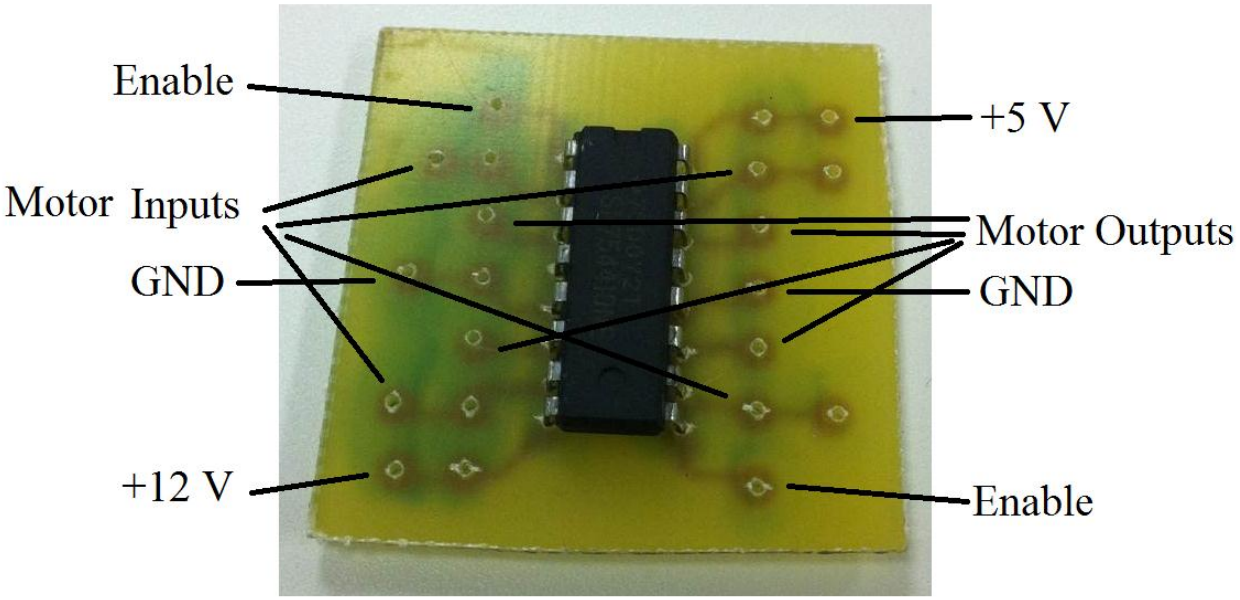



Figure 56: This shows one of the SN754410NE motor driver chips. Each motor will have one of these chips.

Some testing was done to find the relationship between the amount of voltage used to power the motors and the amount of maximum amount of torque that the motors could supply. To test this, the voltage used to power the motors was ranged from 5 to 12 V. A weight was hung from the shaft of the motor using string and more weights were added until the motor stopped turning. The torque was then calculated and recorded. This data can be seen in the graph on the next page.

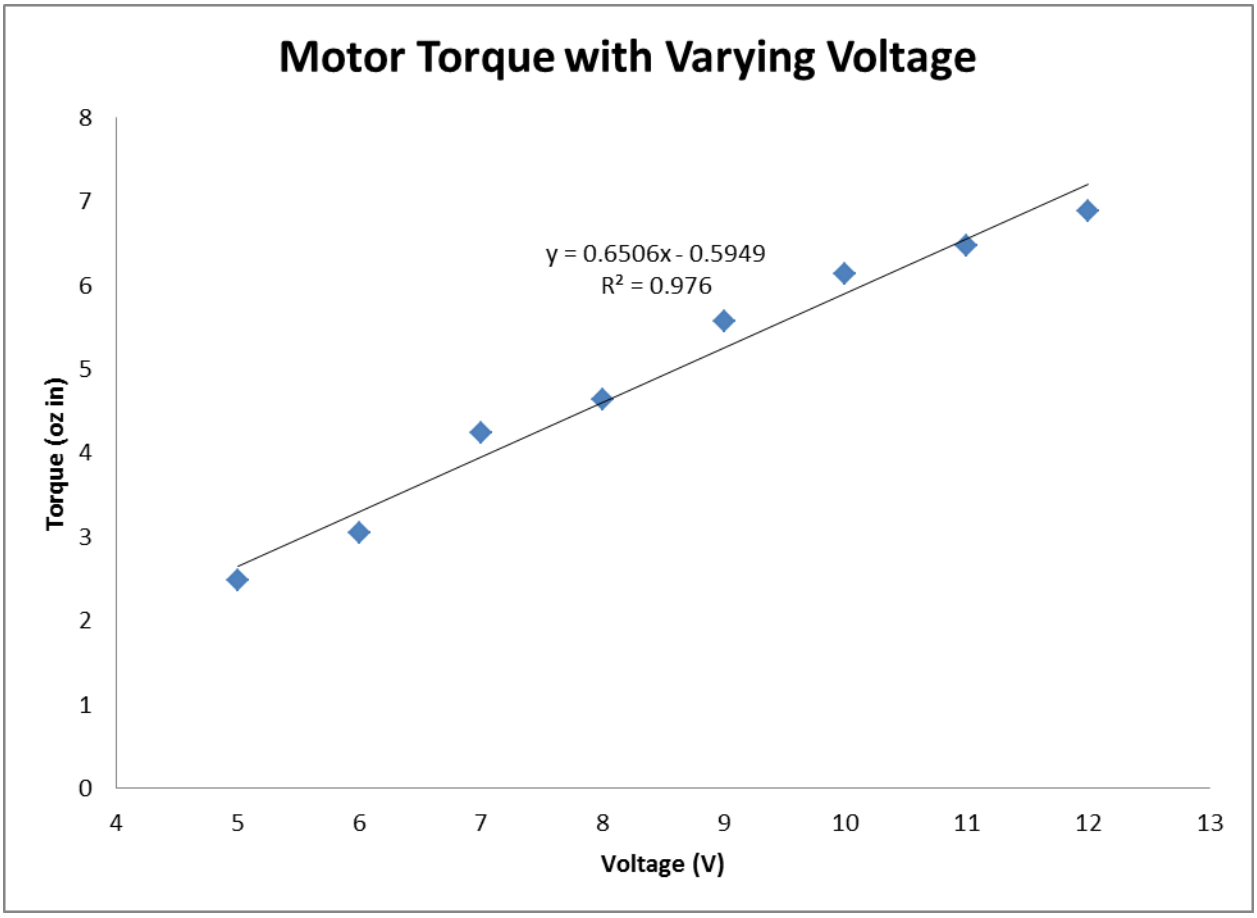



Figure 57: This shows the graphical representation of torque vs. voltage for the motors

Before doing this experiment the amount of voltage being used to power the motors was 5 V and there was very rarely a problem with the motor not having enough torque. Now that 12 V is going to be used, the amount of torque has been more than doubled, and there should not be any jamming problems due to an insufficient amount of torque. The motors don't ever pull more than 0.3 A of current and the half-h drivers are rated for up to 1 A. There have not been any problems with this in the testing that has been done so far.

Force Sensor

One of the requirements of the project is that the device must be reliable, meaning it needs to dispense correctly consistently. The sensor will be able to fulfill the requirement in that it will make sure that once a pill has been dropped the dispensing will stop.

Initial Design

There was going to be four sensors placed to cover the whole area taken up by the tray where the pills were dispensed. A different spike would signal when there had been more than one pill dispensed at a time. The spikes would be compared and read by the microprocessor to determine when to stop the motors. The sensors selected are force sensors, FSR 402 from Interlink Sensors. See Appendix G. They need 5V to operate and their reading force is from 0.1N up to 10N. It was going to be placed at the bottom of the device.

New Design Construction and Progress

Since the platform where the pills are being dispensed is 0.1016 x 0.0508 m (4 x 2 in), one sensor (as opposed to four) placed in the center can recognize if a pill has been dropped anywhere in that area. To prevent the sensor from reading vibrations on the counter or table, the sensor is now in a swinging platform that sits near the bottom of the device.

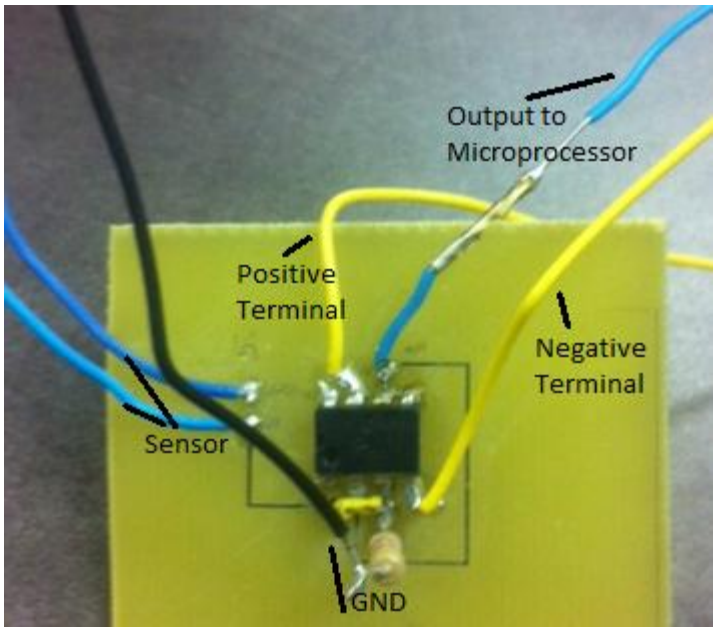



Figure 58. Sensor Circuitry

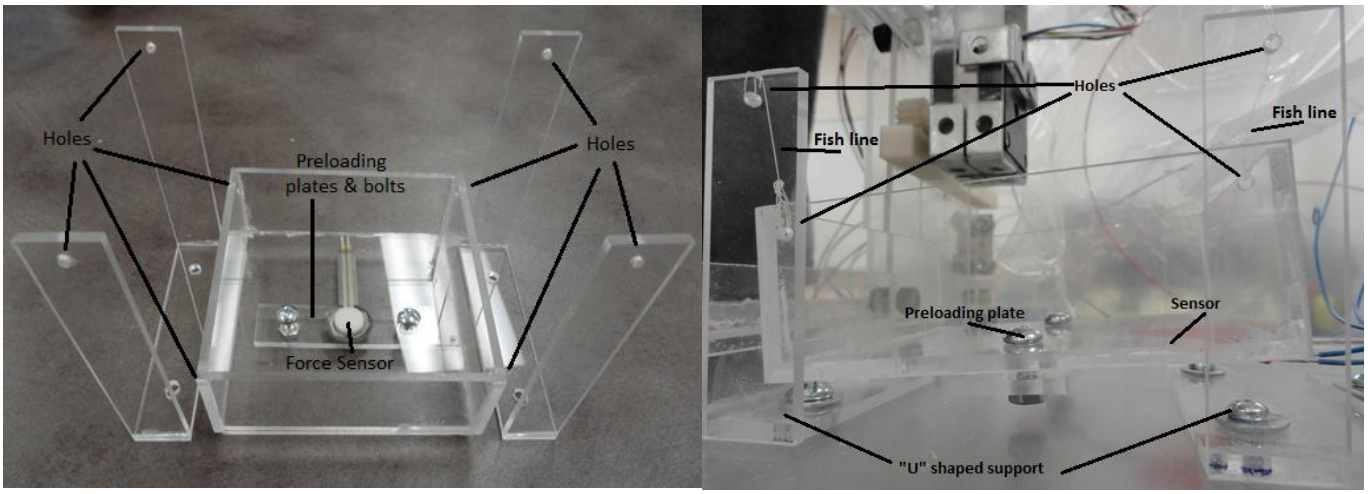



Figure 59. Since the sensor needs a preload to be activated, a preloading plate and bolts function as necessary weight.

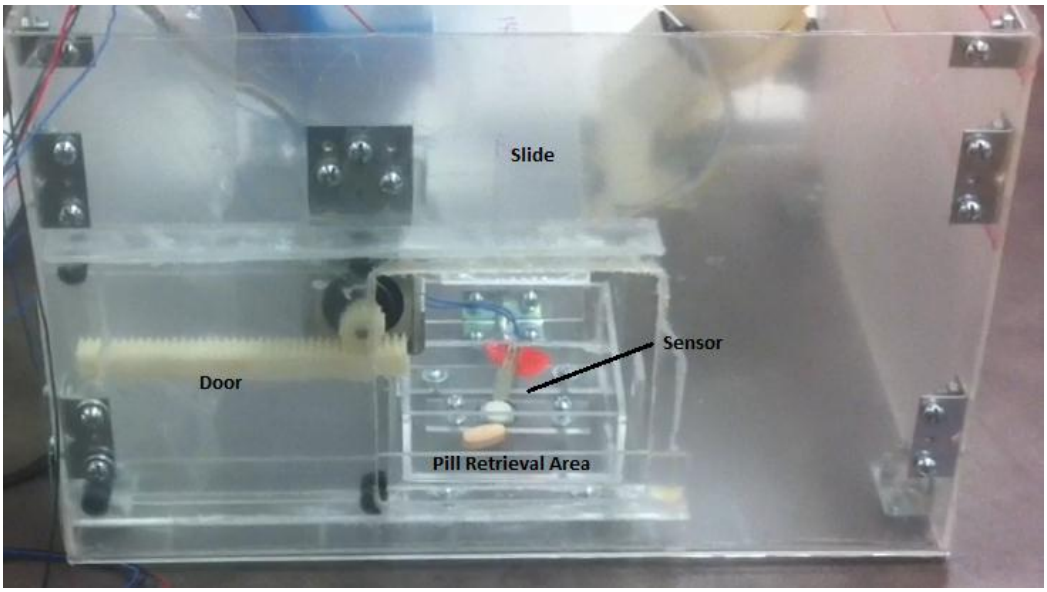



Figure 60. Swinging platform integrated in the device

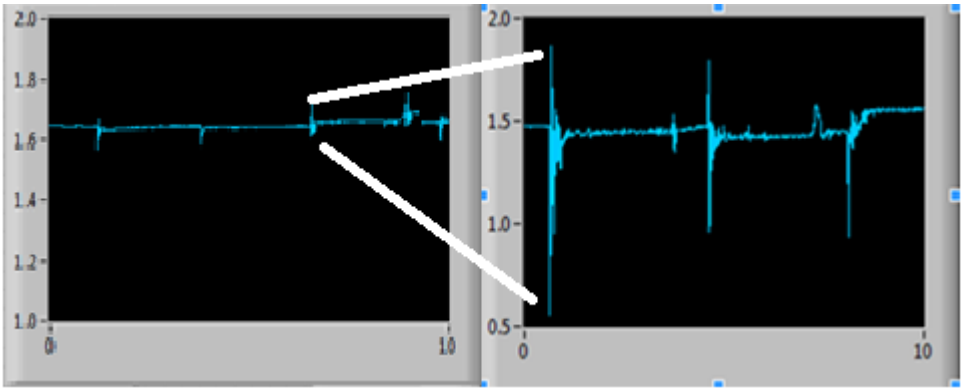



Figure 61. Sensor's outputs from outside vibrations vs. pills dropping

The left portion of Figure 61 shows the sensor's output from vibrations outside the device that does not activate the sensor. The right portion shows when pills drop into the sensor. This peak is the one the microprocessor reads and activates the sensor.

Inverter Design

The schematic in Figure 62 converts positive to negative voltage needed for the op amp in the force sensor to function properly. The 100 uF capacitor charges through the second diode but when the output of the 555 timer is zero, the same capacitor discharges through the first diode and the 0.01 uF capacitor gets charged. Therefore, the intersection of the anode of the second diode and the cathode of the first diode will always be negative with respect to the ground. The negative voltage is slightly lower than the positive one, but the positive voltage tends to be a little higher than its rated voltage.

The schematic on the left shows the DC voltage from the power supply, and the one on the right simulates the testing shown on the pictures below.

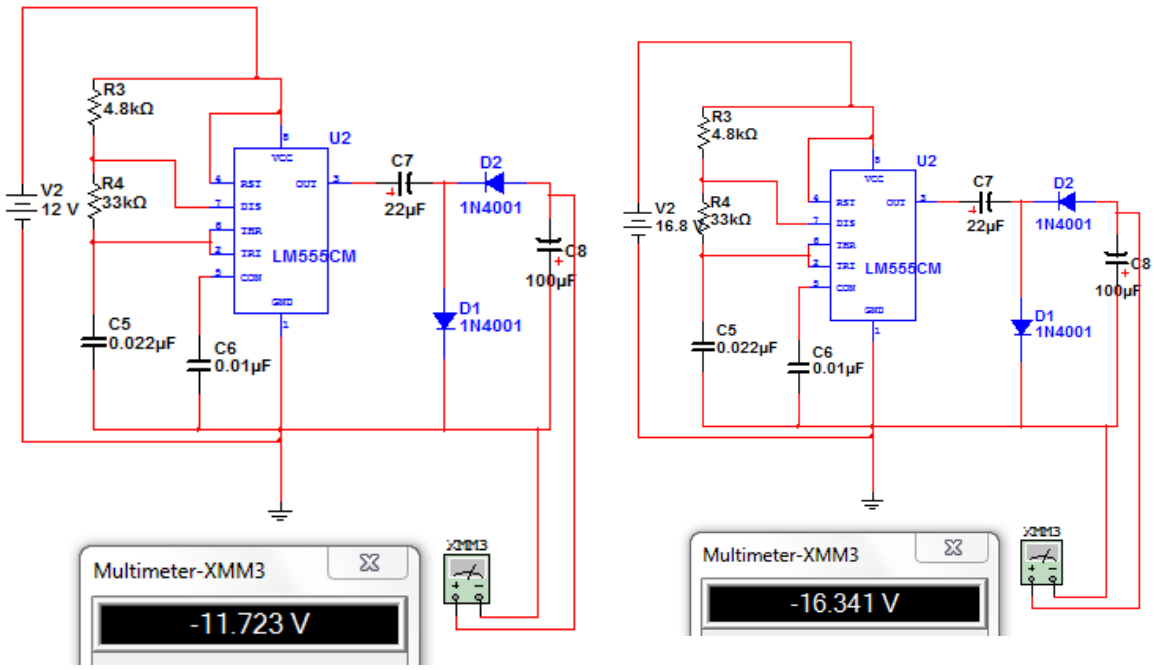



Figure 62. Inverter Multisim Schematic

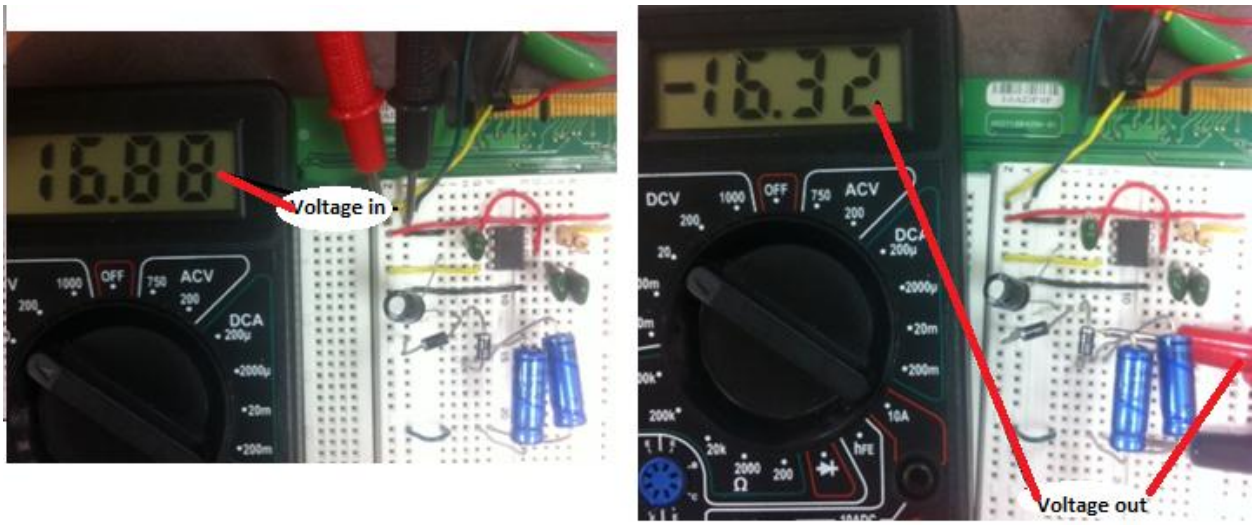



Figure 63. Inverter Testing

Figure 63 shows the testing for the inverter circuit to operate the op amp in the force sensor. Its output voltage is a few volts lower than the input voltage, yet it functions properly.

## User Interface System

Overview:

The purpose of this system is to allow the caretaker to set up the device and for the patient to receive their medication. More specifically, the caretaker will use an LCD screen and keypad to initially connect the device to a Wi-Fi network. Then the caretaker will use a separate computer connected to that same wireless network to program the device to dispense the patient's medication in the right amount and at the correct times. When the alarm sounds for the patient to retrieve their medication, the patient will scan an RFID chip and the device will allow access to the dispensed medication and display any special instructions that go with that medication on the LCD screen.

LCD Screen:

This will be used for initially setting up the device with the wireless network and for giving any special instructions to the patient when taking medication. The screen can display four lines of 16 characters at one time, so when connecting the device to the Wi-Fi network the top two lines will prompt the user to enter the name of the network and the second two lines will display characters as they type them. After that the top two lines will prompt the user for the password and the bottom two lines will again be used to display characters as they are typed. All 64 characters will be used for displaying special instructions to the patient for taking medication. Currently, the code required for initializing the screen, sending characters and all other necessary commands has been written and thoroughly tested.

Currently a header file that has functions for initializing the LCD, printing characters to the screen, printing whole strings to the screen, clearing the screen, and moving the cursor has been written. This program has been integrated with several other programs in order to output messages to the LCD screen. For example, the program for the RFID reader outputs a confirmation message to the LCD screen when a card is detected, and for the keypad the buttons pressed are output onto the LCD screen. The contrast for the LCD is controlled using a single potentiometer. The backlight for the LCD will be controlled by the processor using a single output and a transistor. No more work is anticipated to be done with using this device other than to solder it to the control system PCB.

Figure 64. This is a picture of the LCD screen with a printed message

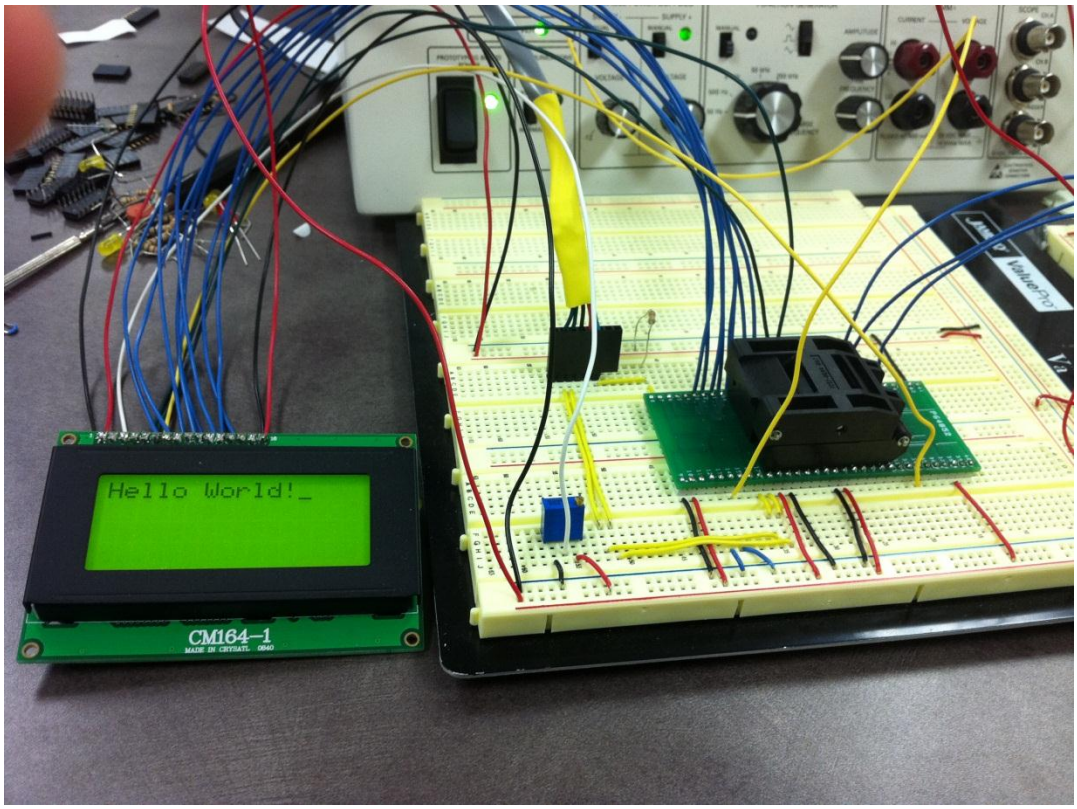



Figure 65. This shows the LCD connected to the processor

Keypad and Encoder:

This will be used with the LCD screen for initially setting up the device with the wireless network. It also needs to be inexpensive and use very little power. This keypad was also found at www.futurlec.com and was selected to be used with the device. The cost of the device is only $3 and uses similar power to the other keypads. When entering in the network information, the caretaker will have to press the buttons multiple times to enter letters. For example, to enter a "b" the caretaker would push the number two key three times. Upper case letters come after the lowercase letters, so to get a "B" the caretaker would press the number two key six times total. The star key will be used as backspace and the "#" key will be used to signal that they are done entering characters. These will be clearly labeled on the keypad and explained in the user manual. This is fairly complicated which is unfortunate, but it will generally only be used once for initial device setup. An EDE1144 keypad encoder will be used with this keypad. It has four outputs that will be read by the processor for determining what key was pressed. It also sends an interrupt signal to the processor so that the processor knows when to read the data lines. These components have been put onto a breadboard and tested. All of the code required for the processor to read in data from the keypad as earlier specified has also been completed. For a detailed look at the keypad and encoder's features and some code, see Appendix D.

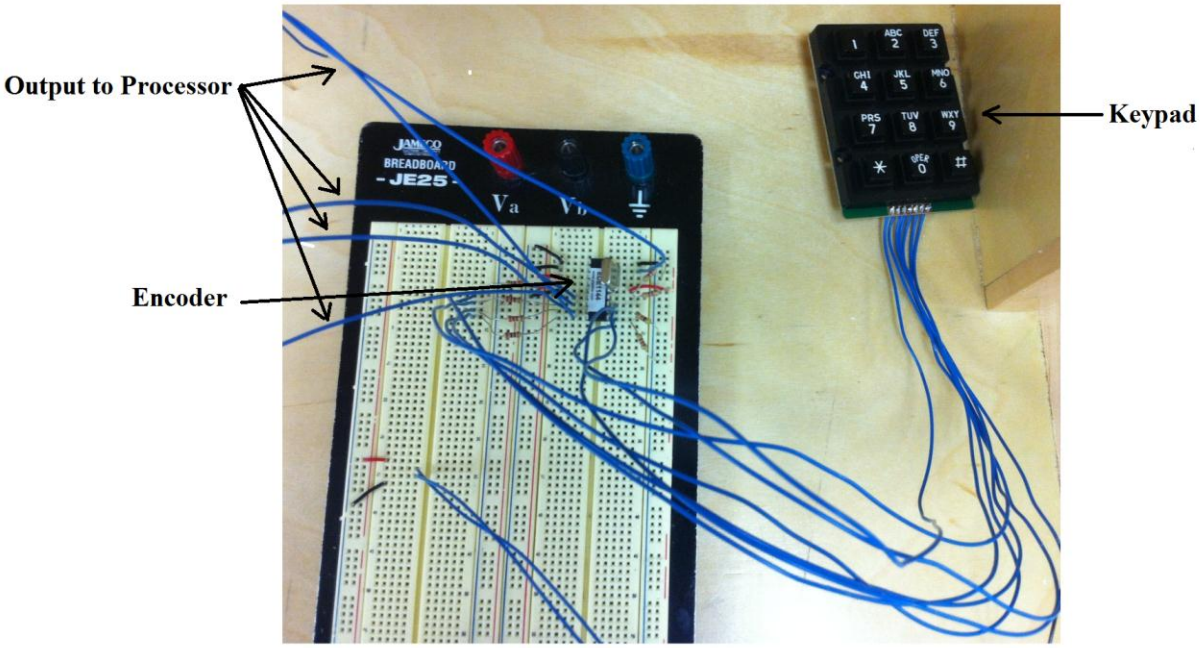



Figure 66. This shows the keypad connected to the encoder. The wires going to the left connect to the processor.

RFID Reader:

The reader has been put into a breadboard and connected to the processor. It sends data serially through its one output line at 2400 bps, 8 bits, 1 stop bit and no parity. Using the processors built in UART (Universal Asynchronous Receiver and Transmitter), I was able to complete the code required to generate an interrupt when a card is read and data is sent to the processor. Currently it does not check the data to make sure that what was sent matches the card ID, but this will hopefully be resolved soon. As of now, when a card is read, the processor prints out a confirmation message to the LCD screen and disables the reader. The reader's features and the written code that goes with it can be seen in Appendix E.

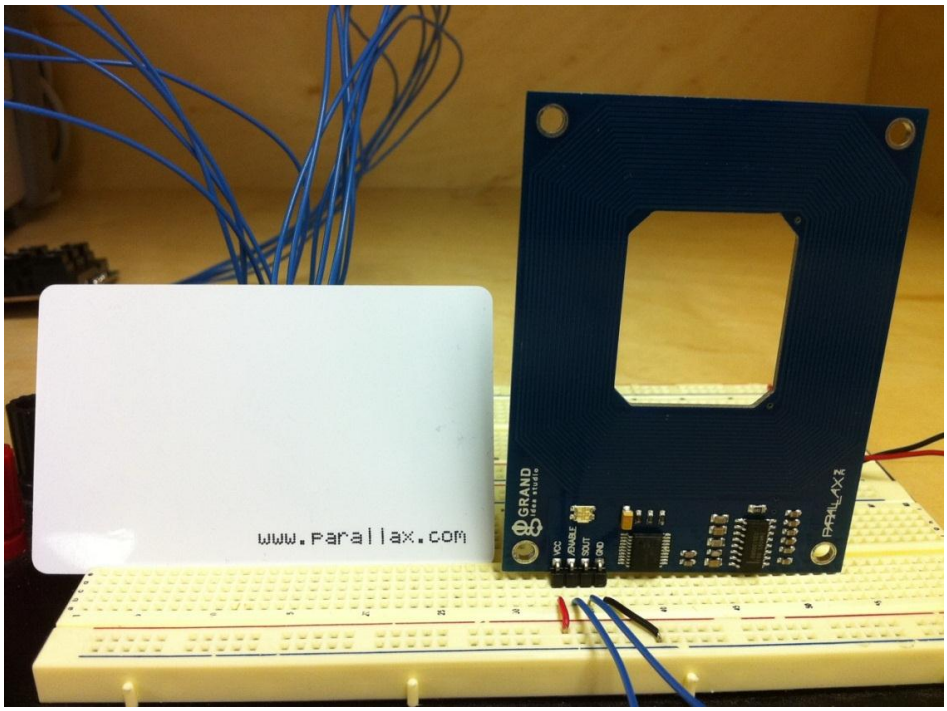
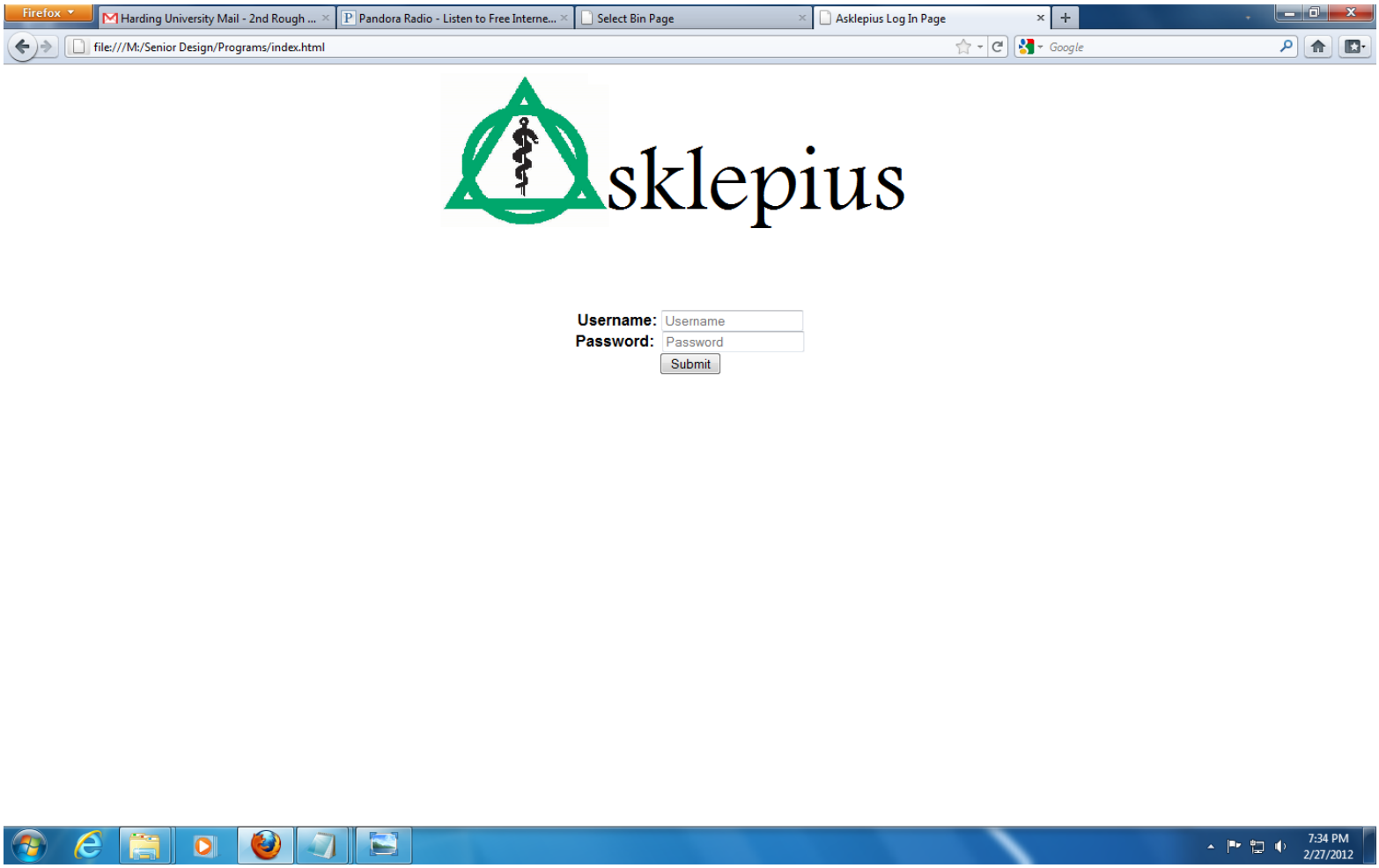
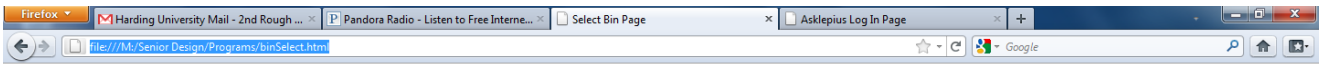



Figure 67. This shows the RFID Reader and one of the RFID chips that came with it.

GUI:

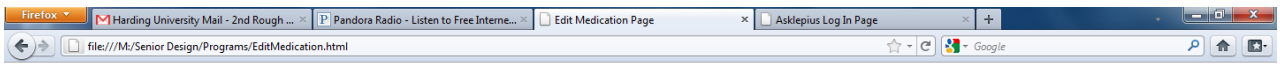
The following pages contain screen shots of the initial user interface that will be used by the caretaker to set up the device. They will first log in with a username and password. Then they will be able to change medication information, the time in the real time clock and add or remove emails to be notified when something goes wrong.





Edit Medication Change Clock Setup Email

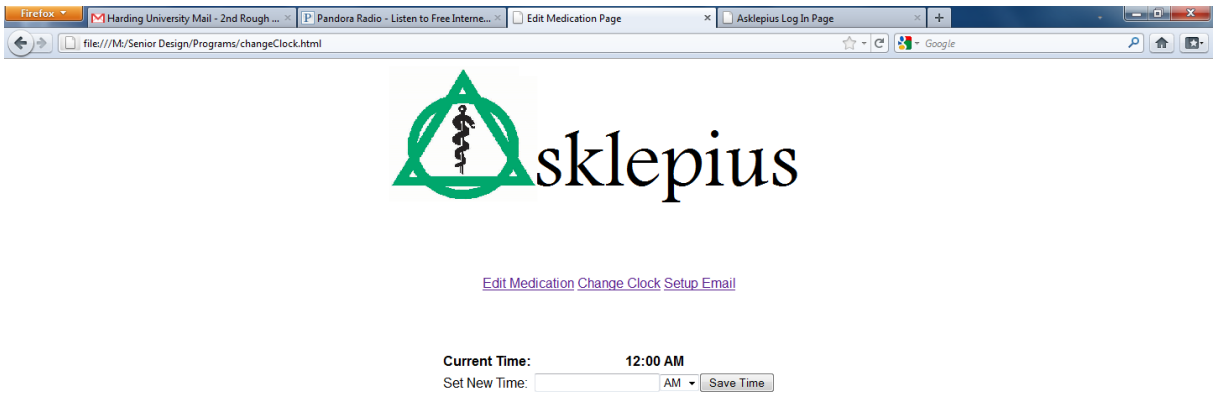
**Select a bin:**



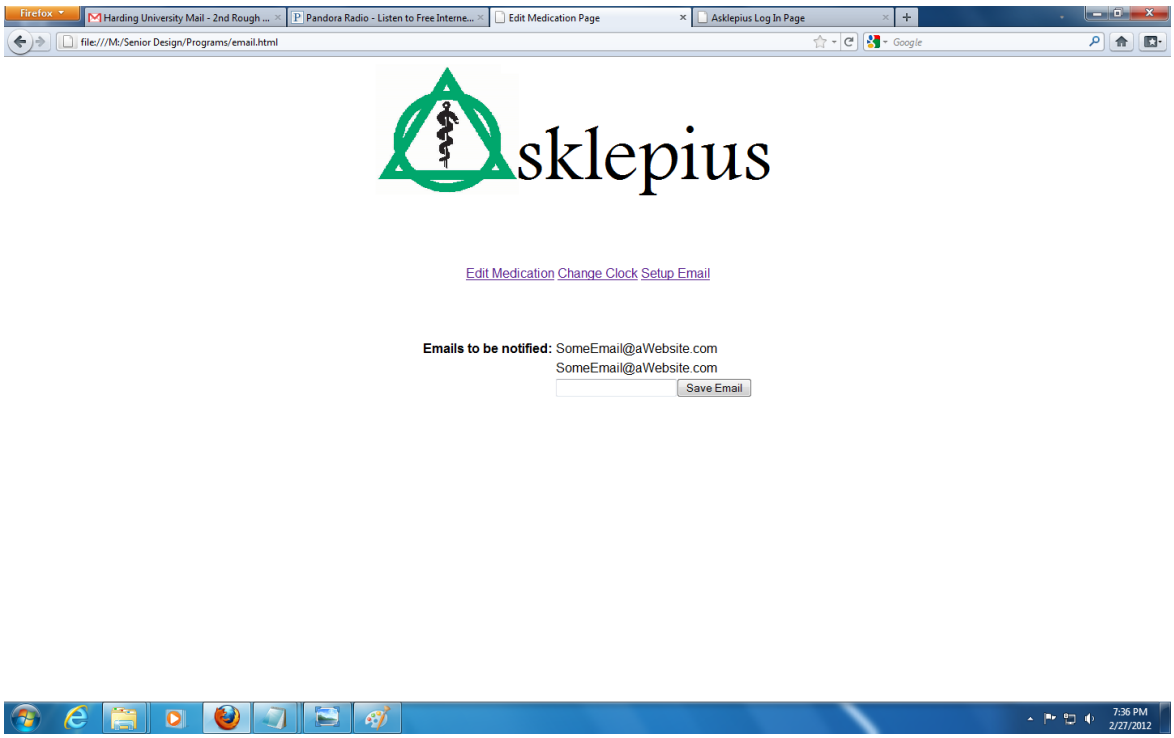
Edit Medication Change Clock Setup Email

**Bin 1:**

Name of Medication:
Number of Pills:
Daily Schedule: AM Delete Time
AM Delete Time
AM Delete Time
Add New Time
Instructions: Put any special instructions here


Harding University Mail - 2nd Rough ...
Pandora Radio - Listen to Free Interne...
Edit Medication Page
Asklepius Log In Page
file:///M:/Senior Design/Programs/changeClock.html
sklepius
Edit Medication Change Clock Setup Email
Current Time: 12:00 AM
Set New Time: AM Save Time

file:///M:/Senior Design/Programs/changeClock.html
7:36 PM
2/27/2012


Harding University Mail - 2nd Rough ...
Pandora Radio - Listen to Free Interne...
Edit Medication Page
Asklepius Log In Page
file:///M:/Senior Design/Programs/email.html
sklepius
Edit Medication Change Clock Setup Email
Emails to be notified: SomeEmail@aWebsite.com
SomeEmail@aWebsite.com
Save Email
7:36 PM
2/27/2012

**Alarm Design and Progress**

Initial Design

The alarm will notify the patient the pill is ready to be taken. One of the requirements for the alarm is that it should have a sound intensity between 80dB and 90dB. It should also sound each time the device is ready to dispense pills.

Alarm Construction and Testing

The sole component in this system is the Mallory Sonalert MSS5M1, specifications can be found in Appendix F. It is a buzzer that outputs 88dB with a frequency of 975Hz.

The alarm is used with the high priority. The high priority has several beeps repeatedly and it is the loudest. This option has been chosen because it fulfills the sound intensity requirement to be between 80-90dB aiming to reach various places in a household with the same intensity.

The 5VDC is a signal that comes from the microprocessor and activates a transistor to power the component. Figure 68 shows the alarm circuitry integrated with the microprocessor.

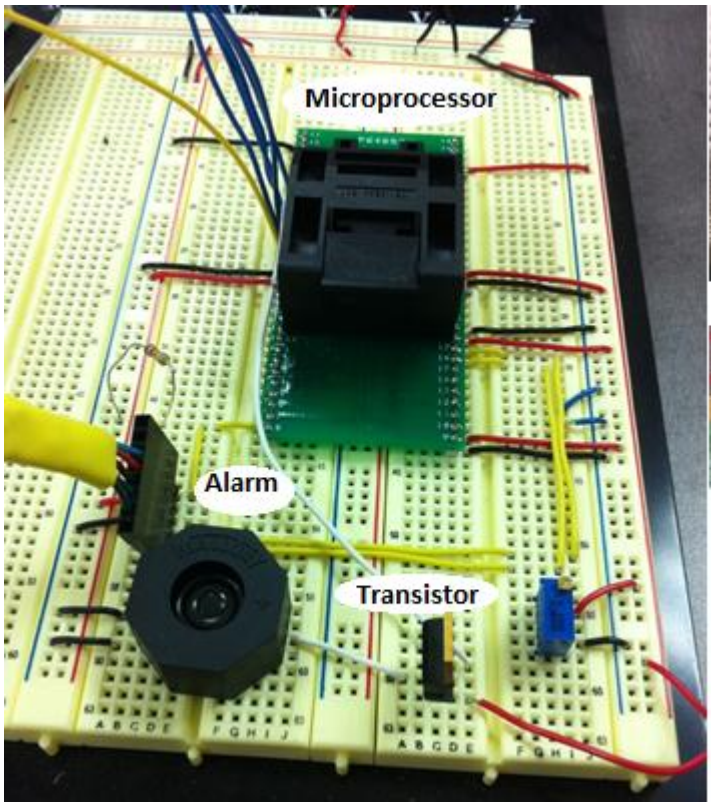



Figure 68. Alarm circuitry

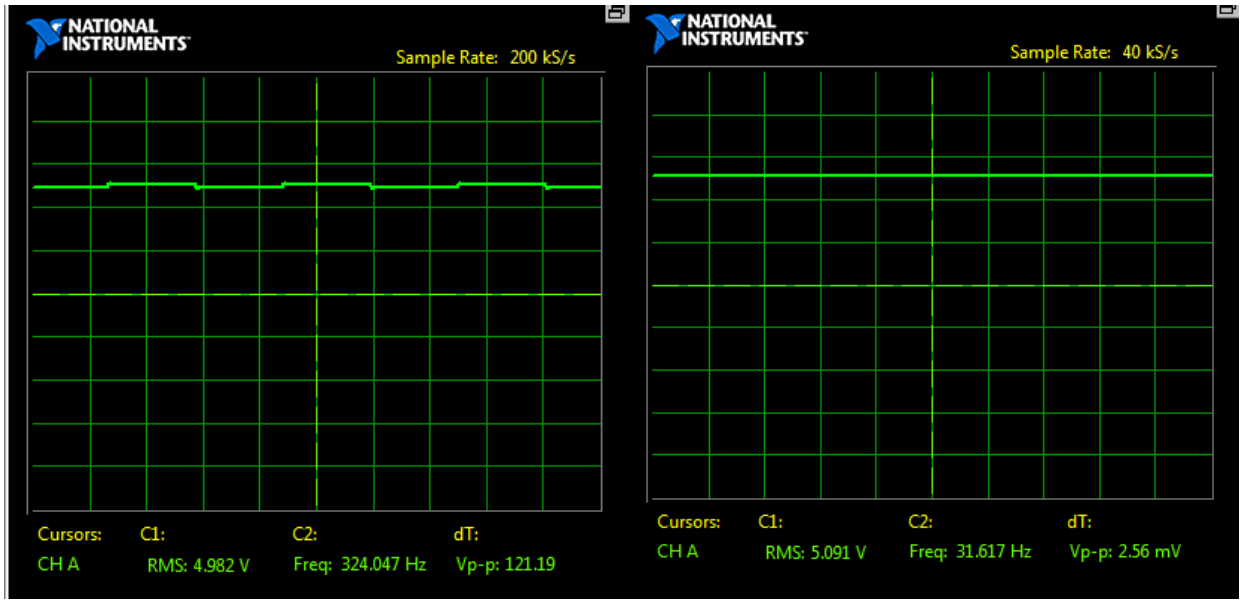

NATIONAL INSTRUMENTS
Sample Rate: 200 kS/s
Cursors: C1: C2: dT:
CH A RMS: 4.982 V Freq: 324.047 Hz Vp-p: 121.19
NATIONAL INSTRUMENTS
Sample Rate: 40 kS/s
Cursors: C1: C2: dT:
CH A RMS: 5.091 V Freq: 31.617 Hz Vp-p: 2.56 mV

Figure 69. Oscilloscope Reading of the Alarm

An oscilloscope was used to test the output of the system. The square peaks in Figure 69 show when the alarm is on, and when the alarm is off, the output is constant in 5V. There is a greater frequency when the alarm is on.

Figure 70 shows two decibel meters that were used to test the decibel range of the alarm when it was on to meet the sound intensity requirement. The first meter simply shows an average reading. The second meter shows three readings, the current reading, 88 dB, was at the moment when the alarm was on, the average reading, 70 dB, is the room with the air conditioning system on and the alarm is off, and the highest reading, 85 dB, shows the previous set of beeps.

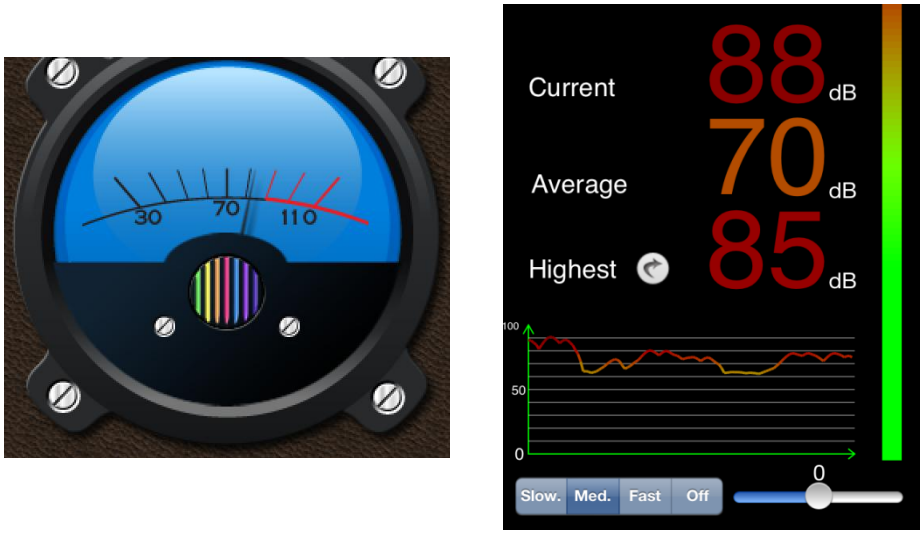



Figure 70 Sound intensity testing for the alarm in decibels

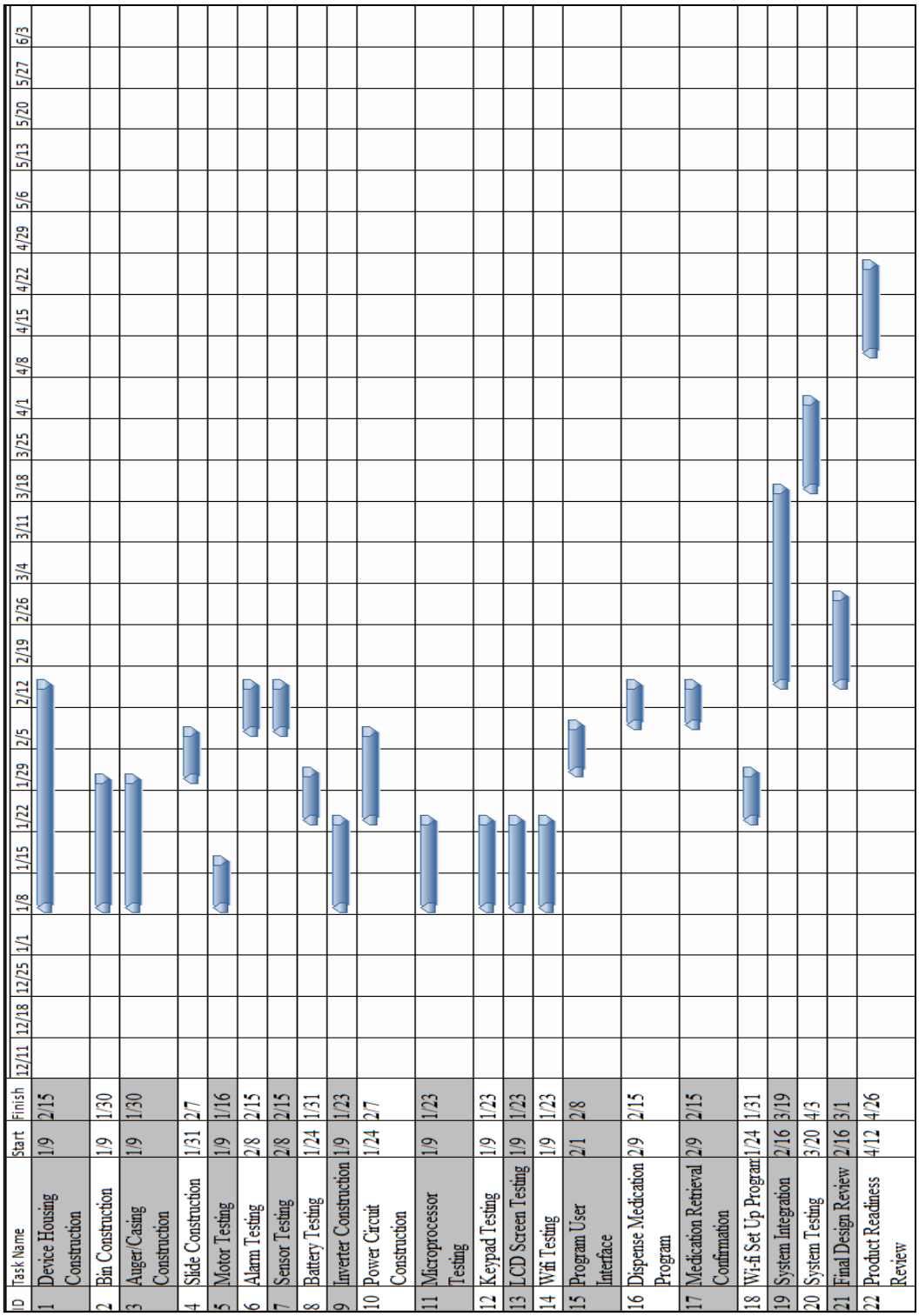
# Project Plan

## Organization and Management

The Asklepius Pill Dispenser team comprises two mechanical engineering students, one computer engineering student, and one electrical engineering student. The project's management and design tasks will be distributed among the team into the following responsibilities:

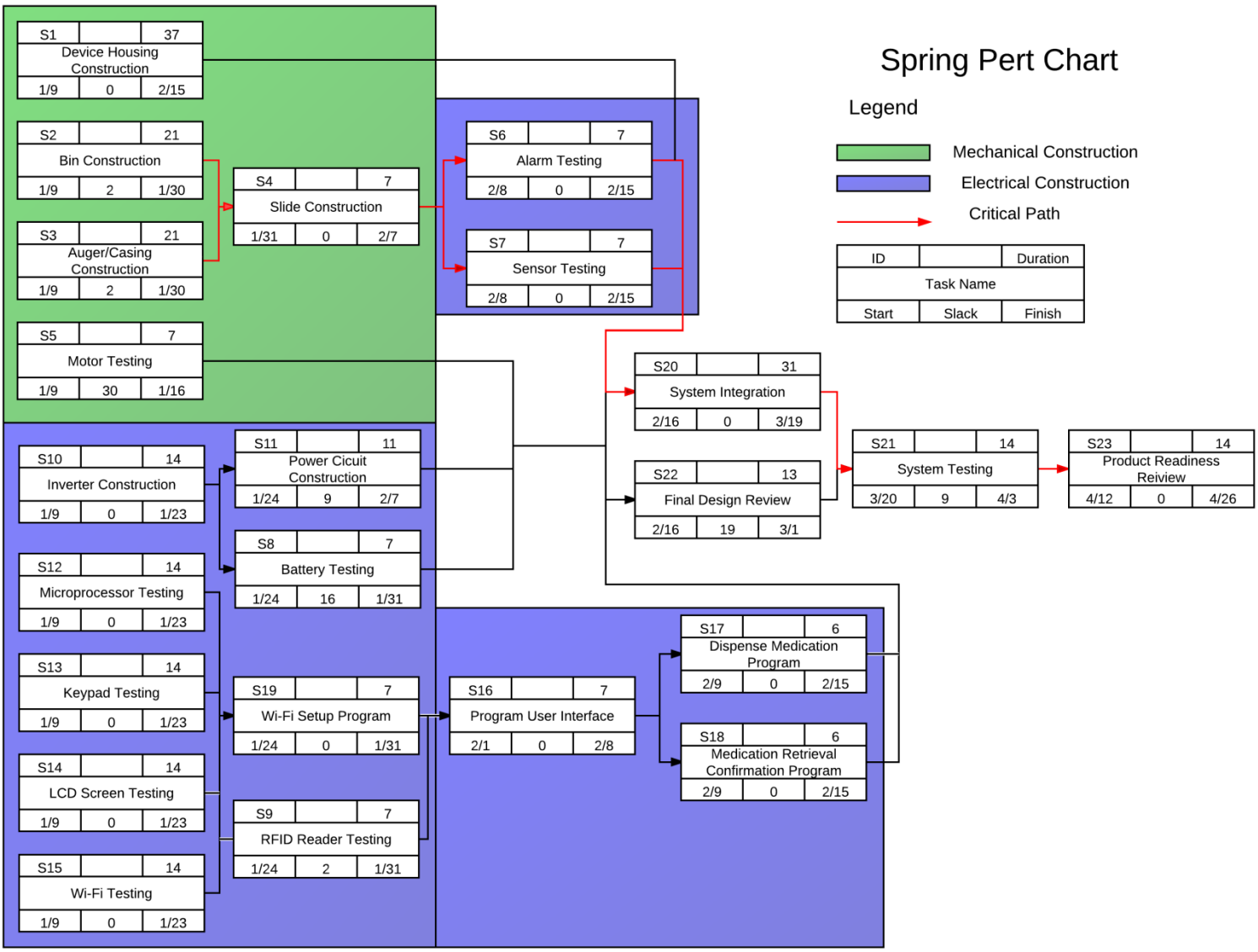
- **Andrew Combs** (Mechanical Engineer) – Andrew is the team leader of this project. He is responsible for making sure that the subsystems are completed and integrated on time. He is responsible for making sure that all reports and presentations are completed on time. He is responsible for the design and construction of the auger/casing mechanism. Andrew will work with Jeff to make sure all of Jeff's tasks are completed.
- **Jeff Wood** (Mechanical Engineer) – Jeff is responsible for making the SolidWorks drawings of the design. He is responsible for the design and construction of the device housing, pill storage bins, slide, and pill retrieval area. He will work with Andrew to make sure that all of Andrew's tasks are completed.
- **Ethan Lilly** (Computer Engineer) –Ethan is responsible for programming the microprocessor and constructing the user interface, which includes the LCD screen, keypad, graphical user interface and the Wi-Fi interface. Ethan will back up Emilia to make sure she completes her tasks.
- **Emilia Faraj** (Electrical Engineer) – Emilia is responsible for maintaining the budget. She is responsible for the electrical designs for the power supply, the alarm, and the sensors. She will work with Andrew in the electromechanical components of the dispensing mechanism. She will back up Ethan to make sure he completes his tasks.

# Gantt Chart: Spring 2012



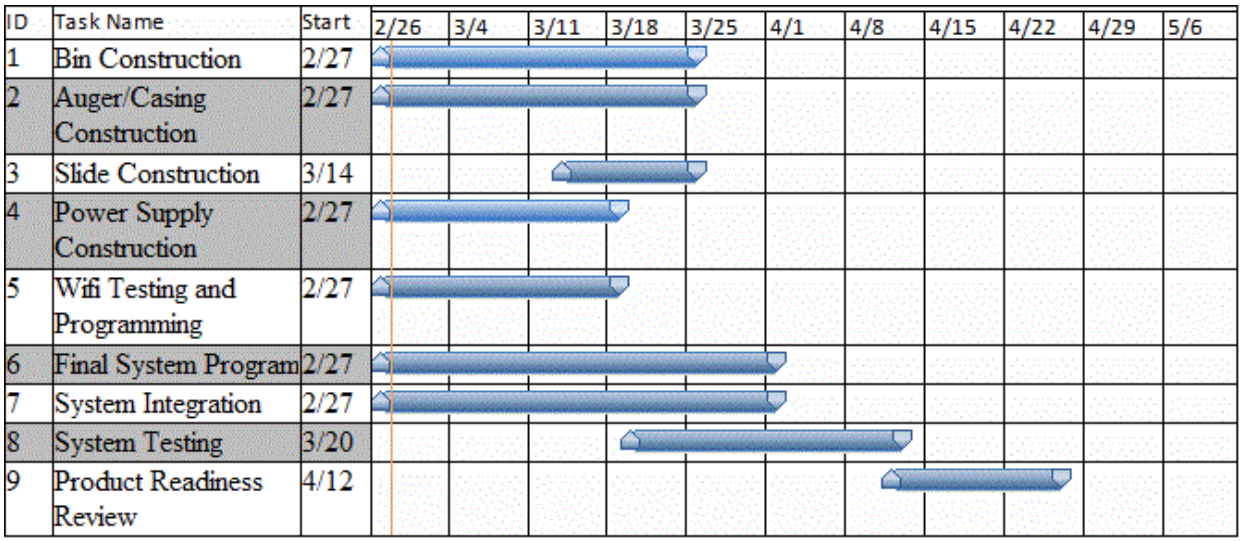
| ID | Task Name | Start | Finish |
|---|---|---|---|
| 1 | Device Housing Construction | 1/9 | 2/15 |
| 2 | Bin Construction | 1/9 | 1/30 |
| 3 | Auger/Casing Construction | 1/9 | 1/30 |
| 4 | Slide Construction | 1/31 | 2/7 |
| 5 | Motor Testing | 1/9 | 1/16 |
| 6 | Alarm Testing | 2/8 | 2/15 |
| 7 | Sensor Testing | 2/8 | 2/15 |
| 8 | Battery Testing | 1/24 | 1/31 |
| 9 | Inverter Construction | 1/9 | 1/23 |
| 10 | Power Circuit Construction | 1/24 | 2/7 |
| 11 | Microprocessor Testing | 1/9 | 1/23 |
| 12 | Keypad Testing | 1/9 | 1/23 |
| 13 | LCD Screen Testing | 1/9 | 1/23 |
| 14 | Wifi Testing | 1/9 | 1/23 |
| 15 | Program User Interface | 2/1 | 2/8 |
| 16 | Dispense Medication Program | 2/9 | 2/15 |
| 17 | Medication Retrieval Confirmation | 2/9 | 2/15 |
| 18 | Wi-fi Set Up Program | 1/24 | 1/31 |
| 19 | System Integration | 2/16 | 3/19 |
| 20 | System Testing | 3/20 | 4/3 |
| 21 | Final Design Review | 2/16 | 3/1 |
| 22 | Product Readiness Review | 4/12 | 4/26 |

# Pert Chart: Spring 2012



After looking at the scheduling made from last semester some revisions needed to be made. Our group has for the most part stayed on schedule and completed task on time, but it became apparent that some of the tasks needed some iteration before being finalize. For example, the bin and auger/casing construction has not been completed because the design for this needs to be slightly adjusted to make sure that our group will meet all of the requirements. Once the design is completely finished, then it will be a simple matter of printing it out repeatedly on the 3D printer. This has also caused the slide construction to be pushed back slightly because its dimensions relies on the bin design. The power supply and back up battery circuits have all been printed and some have been integrated to make sure that they will meet the device's power requirements. All of the programming for the electronic components has been done for each part individually except for the Wi-Fi transceiver. A large amount of integration into the final device has been done as well. Moving forward our group will work quickly to finish up any of the tasks left over and continue to integrate components into the final device as they are completed. A new Gantt chart has been made showing the current plan from now until the end of the project.

## New Gantt Chart



## Budget

This section contains two budgets. The first budget shows everything that our group will have to place an order for and spend the group money on. The second budget is the supplement budget, which shows what the prototype would cost if the group did not have access to any free items. Here are some of the updates to the budget: the professional PCB has been ordered, a power supply was ordered, several ICs were purchased including the keypad encoder and the half-h motor drivers, a SchmartBoard was ordered to help with soldering the processor, the plexiglass was first cut professionally into smaller boards that could be used in the mill and finally the estimate for the 3D print material has been updated in the second budget. These purchases were not expensive and our group is still in great shapes for coming in well under budget. The updated budgets can be seen on the following pages.

| Budget | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Vendor** | **Cost/Unit ($)** | **Units** | **Shipping Cost** | **Taxes** | **Total Cost ($)** | **Date Estimated** |
| **Mechanical Components** | | | | | | | |
| Motors | alltronics.com | 8.95 | 10 | 0.00 | 0.00 | 89.50 | 12/1 |
| Plexiglas Sheet (72"x36") | Lowes | 54.98 | 1 | 0.00 | 6.00 | 60.98 | 10/8 |
| Zinc Corner Brace (4 braces in each, screws included) | Lowes | 2.67 | 3 | 0.00 | 0.00 | 8.01 | 10/8 |
| Lock | Lowes | 4.27 | 1 | 0.00 | 0.00 | 4.27 | 12/6 |
| Hinges | Lowes | 2.27 | 1 | 0.00 | 0.00 | 2.27 | 12/6 |
| Bolts and Nuts | Lowes | 5.58 | 1 | 0.00 | 0.00 | 5.58 | 12/6 |
| **Electrical Components** | | | | | | | |
| PCB | www.expresspcb.com | 65.00 | 1 | 0.00 | 0.00 | 65.00 | 10/3 |
| 2 Batteries 9V | Walgreens | 9.49 | 1 | 0.00 | 0.76 | 10.25 | 12/6 |
| Alarm | www.digikey.com | 11.84 | 1 | 0.00 | 0.00 | 11.84 | 10/3 |
| 3.3 V Regulator | www.digikey.com | 2.14 | 2 | 0.00 | 0.00 | 4.28 | 12/1 |
| 15 V Regulator | www.digikey.com | 1.87 | 1 | 0.00 | 0.00 | 1.87 | 12/5 |
| Transformer | www.ebay.com | 19.99 | 1 | 0.00 | 0.00 | 19.99 | 10/3 |
| Keypad Encoder | www.jameco.com | 5.19 | 1 | 1.51 | 0.00 | 6.70 | 1/18 |
| Power Supply | www.digikey.com | 41.00 | 1 | 2.80 | | 50.05 | 1/27 |
| SN754410NE Ics | www.jameco.com | 1.95 | 10 | 3.11 | 0.00 | 22.61 | 1/28 |
| Crystal, 4 mHz | www.jameco.com | 0.59 | 1 | 0.00 | 0.00 | 0.59 | 1/28 |
| 74HC154 IC | www.jameco.com | 0.99 | 1 | 0.00 | 0.00 | 0.99 | 1/28 |
| **Computer Components** | | | | | | | |
| Wi-Fi Module | www.microchip.com | 23.74 | 1 | 0.00 | 6.78 | 30.52 | 10/8 |
| LCD Screen | www.futurlec.com | 12.90 | 1 | 0.00 | 0.00 | 12.90 | 10/8 |
| Keypad | www.futurlec.com | 2.90 | 1 | 0.00 | 0.00 | 2.90 | 10/8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| RFID Reader/Chips | www.parallax.com | 39.99 | 1 | 0.00 | 0.00 | 39.99 | 11/10 |
| Schmart Board | www.schmartboard.com | 7.99 | 1 | 7.90 | 0.00 | 15.89 | 1/29 |
| | | | | | | | |
| **Total ($)** | | | | | | **466.98** | |
| **Contingency ($)** | | | | | | **563.02** | |
| **Budget ($)** | | | | | | **1030.00** | |

| Budget 2 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Vendor** | **Cost/Unit ($)** | **Units** | **Shipping Cost** | **Taxes** | **Total Cost ($)** | **Date Estimated** |
| **Mechanical Components** | | | | | | | |
| Motors | alltronics.com | 8.95 | 10 | 0.00 | 0.00 | 89.50 | 12/1 |
| Plexiglas Sheet (72"x36") | Lowes | 54.98 | 1 | 0.00 | 4.39 | 59.37 | 10/8 |
| Plexiglas Cut | Landis Glass Co. | NA | NA | 10.00 | 0.00 | 10.00 | 1/30 |
| Zinc Corner Brace | Lowes | 2.67 | 3 | 0.00 | 0.64 | 8.65 | 10/8 |
| Lock | Lowes | 4.27 | 1 | 0.00 | 0.56 | 4.83 | 12/6 |
| Hinge | Lowes | 2.27 | 1 | 0.00 | 0.03 | 2.30 | 12/6 |
| Bolts and Nuts | Lowes | 5.58 | 1 | 0.00 | 0.45 | 6.03 | 12/6 |
| Auger/Casing Material | Engineering Department | 5.00 | 40 | 0.00 | 0.00 | 200.00 | 10/13 |
| **Electrical Components** | | | | | | | |
| PCB | www.expresspcb.com | 65.00 | 1 | 0.00 | 0.00 | 65.00 | 10/3 |
| 2 Batteries 9V | Walgreens | 9.49 | 1 | 0.00 | 0.76 | 10.25 | 12/6 |
| Alarm | www.digikey.com | 11.84 | 1 | 0.00 | 0.00 | 11.84 | 10/3 |
| 3.3 V Regulator | www.digikey.com | 2.14 | 2 | 0.00 | 0.00 | 4.28 | 12/1 |
| 15 V Regulator | www.digikey.com | 1.87 | 1 | 0.00 | 0.00 | 1.87 | 12/5 |
| Power Supply | www.digikey.com | 41.99 | 1 | 4.00 | 4.06 | 50.05 | 1/26 |
| Transformer | www.ebay.com | 19.99 | 1 | 0.00 | 0.00 | 19.99 | 10/3 |
| Force Sensors | www.interlinkelec.com | 6.44 | 1 | 0.00 | 0.00 | 0.00 | 10/20 |
| Keypad Encoder | www.jameco.com | 5.19 | 1 | 1.51 | 0.00 | 6.70 | 1/18 |
| SN754410NE Ics | www.jameco.com | 1.95 | 10 | 3.11 | 0.00 | 0.00 | 1/28 |
| Crystal, 4 mHz | www.jameco.com | 0.59 | 1 | 0.00 | 0.00 | 0.59 | 1/28 |
| 74HC154 IC | www.jameco.com | 0.99 | 1 | 0.00 | 0.00 | 0.99 | 1/28 |
| PCB (etched) | Engineering Department | 4 | 3 | 0 | 0 | 8.00 | 1/30 |
| **Computer Components** | | | | | | | |
| Microprocessor | www.microchip.com | 5.00 | 4 | 0.00 | 0.00 | 2.90 | 10/8 |
| Wi-Fi Module | www.microchip.com | 23.74 | 1 | 0.00 | 6.78 | 39.99 | 10/8 |
| LCD Screen | www.futurlec.com | 12.90 | 1 | 0.00 | 0.00 | 0.00 | 10/8 |
| Keypad | www.futurlec.com | 2.90 | 1 | 0.00 | 0.00 | 0.00 | 10/8 |
| RFID Reader/Chips | www.parallax.com | 39.99 | 1 | 0.00 | 0.00 | 0.00 | 11/10 |
| Schmart Board | www.schmartboard.com | 7.99 | 1 | 7.90 | 0.00 | 15.89 | 1/29 |
| | | | | | | | |
| **Total ($)** | | | | | | **619.02** | |
| **Contingency ($)** | | | | | | **410.98** | |
| **Budget ($)** | | | | | | **1030.00** | |

# References

1.Pueblo, Colorado, Federal Information Center. Medication advice for seniors. (http://www.pueblo.gsa.gov/cic_text/health/meds4old/697_old.html)

2. Minnesota Board on aging. (http://www.mnaging.org/pdf/Prescription%20Drug%202002.PDF)

3. Shopping page for a competing pill dispenser at Wheel Chair Select. (http://www.wheelchairselect.com/Telemergency-royalty100-VCW1000.html)

4. Dimensions Guide. (http://www.dimensionsguide.com/average-kitchen-dimensions/)

5. RadioShack's website. (http://www.radioshack.com/product/index.jsp?productId=2103667)

6. Shigley's Mechanical Engineering Design Ninth Edition. Page 416.

# Appendices

# Appendix A

## Microprocessor

# High-Performance, 16-bit Digital Signal Controllers

**Note:** This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the "*dsPIC30F Family Reference Manual*" (DS70046). For more information on the device instruction set and programming, refer to the "*16-bit MCU and DSC Programmer's Reference Manual*" (DS70157).

## High-Performance Modified RISC CPU:

- Modified Harvard architecture
- C compiler optimized instruction set architecture with flexible Addressing modes
- 83 base instructions
- 24-bit wide instructions, 16-bit wide data path
- 144 Kbytes on-chip Flash program space (Instruction words)
- 8 Kbytes of on-chip data RAM
- 4 Kbytes of nonvolatile data EEPROM
- Up to 30 MIPS operation:
  - DC to 40 MHz external clock input
  - 4 MHz-10 MHz oscillator input with PLL active (4x, 8x, 16x)
  - 7.37 MHz internal RC with PLL active (4x, 8x, 16x)
- 44 interrupt sources:
  - Five external interrupt sources
  - Eight user selectable priority levels for each interrupt source
  - Four processor trap sources
- 16 x 16-bit working register array

## DSP Engine Features:

- Dual data fetch
- Accumulator write-back for DSP operations
- Modulo and Bit-Reversed Addressing modes
- Two, 40-bit wide accumulators with optional saturation logic
- 17-bit x 17-bit single-cycle hardware fractional/ integer multiplier
- All DSP instructions single cycle
- ±16-bit single-cycle shift

## Peripheral Features:

- High-current sink/source I/O pins: 25 mA/25 mA
- Timer module with programmable prescaler:
  - Five 16-bit timers/counters; optionally pair 16-bit timers into 32-bit timer modules
- 16-bit Capture input functions
- 16-bit Compare/PWM output functions
- 3-wire SPI modules (supports 4 Frame modes)
- $I^2C$™ module supports Multi-Master/Slave mode and 7-bit/10-bit addressing
- Two UART modules with FIFO Buffers
- Two CAN modules, 2.0B compliant (dsPIC306010A)
- One CAN module, 2.0B compliant (dsPIC306015)

## Motor Control PWM Module Features:

- Eight PWM output channels:
  - Complementary or Independent Output modes
  - Edge and Center-Aligned modes
- Four duty cycle generators
- Dedicated time base
- Programmable output polarity
- Dead-Time control for Complementary mode
- Manual output control
- Trigger for A/D conversions

## Quadrature Encoder Interface Module Features:

- Phase A, Phase B and Index Pulse input
- 16-bit up/down position counter
- Count direction status
- Position Measurement (x2 and x4) mode
- Programmable digital noise filters on inputs
- Alternate 16-bit Timer/Counter mode
- Interrupt on position counter rollover/underflow

## Analog Features:

- 10-bit Analog-to-Digital Converter (ADC) with four S/H Inputs:
  - 1 Msps conversion rate
  - 16 input channels
  - Conversion available during Sleep and Idle
- Programmable Brown-out Reset

### Special Microcontroller Features:

- Enhanced Flash program memory:
  - 10,000 erase/write cycle (min.) for industrial temperature range, 100K (typical)
- Data EEPROM memory:
  - 100,000 erase/write cycle (min.) for industrial temperature range, 1M (typical)
- Self-reprogrammable under software control
- Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Flexible Watchdog Timer (WDT) with on-chip, low-power RC oscillator for reliable operation
- Fail-Safe Clock Monitor operation detects clock failure and switches to on-chip, low-power RC oscillator
- Programmable code protection
- In-Circuit Serial Programming™ (ICSP™)
- Selectable Power Management modes
  - Sleep, Idle and Alternate Clock modes

### CMOS Technology:

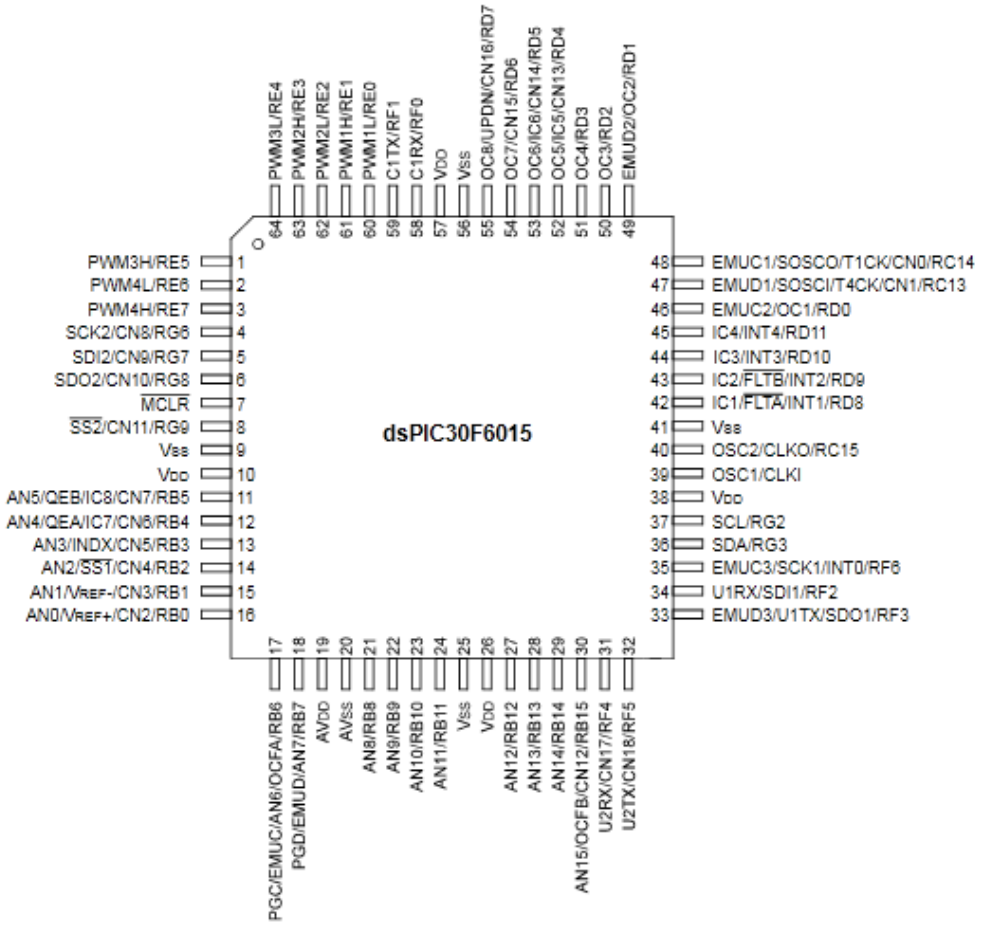
- Low-power, high-speed Flash technology
- Wide operating voltage range (2.5V to 5.5V)
- Industrial and Extended temperature ranges
- Low-power consumption

### dsPIC30F Motor Control and Power Conversion Family

| Device | Pins | Program Mem. Bytes/ Instructions | SRAM Bytes | EEPROM Bytes | Timer 16-bit | Input Cap | Output Comp/Std PWM | Motor Control PWM | A/D 10-bit 1 Msps | Quad Enc | UART | SPI | $I^2C$™ | CAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dsPIC30F6010A | 80 | 144K/48K | 8192 | 4096 | 5 | 8 | 8 | 8 ch | 16 ch | Yes | 2 | 2 | 1 | 2 |
| dsPIC30F6015 | 64 | 144K/48K | 8192 | 4096 | 5 | 8 | 8 | 8 ch | 16 ch | Yes | 2 | 2 | 1 | 1 |

## Pin Diagram

64-Pin TQFP



PROTOTYPE CODE:

```
/*      Ethan Lilly
        Last Modified: 12/5/2011
        This program is used with our most recent prototype. It will step the motor 7.2 degrees
        and then continuously check the A/D converter for about a second for any changes in the
        sensor output. If a pill is dropped on the sensor the program enters an empty infinite
        loop that causes the motor to stop dispensing.
*/

#include <p30f6015.h>
#include <math.h>
#define CrystalFreq 7378200
#define Millisec CrystalFreq/7378

int delay, delay2;

//Functions and Variables with Global Scope:
void ADC_Init(void);

void stepMotor()
{
  int delay = 0;
  int delay2 = 0;

  PORTE = 0x0003;
```

```
  for(delay2=0;delay2<2;delay2++){
  for(delay=0;delay<10000;delay++){}
  }

  PORTE = 0x0006;

  for(delay2=0;delay2<2;delay2++){
  for(delay=0;delay<10000;delay++){}
  }

  PORTE = 0x000C;

  for(delay2=0;delay2<2;delay2++){
                for(delay=0;delay<10000;delay++){}
  }

  PORTE = 0x0009;

  for(delay2=0;delay2<2;delay2++){
    for(delay=0;delay<10000;delay++){}
  }
}

//Functions:
//ADC_Init() is used to configure A/D to convert 16 samples of 1 input
//channel per interrupt. The A/D is set up for a sampling rate of 1MSPS
```

```
//Timer3 is used to provide sampling time delay.
//The input pin being acquired and converted is AN7.
void ADC_Init(void)
{
  TRISB  = 0xFFFF;          //Port B is input
  ADPCFG = 0xFFFB;          //10th channel is sampled and coverted
  ADCON1 = 0x00E0;          //ADC off, output_format=INTEGER
                            //Manual start of convesion
                            //Manual start of sampling
  ADCHS  = 0x0002;          //Connect RB10 on AN10 as CH0 input
  ADCSSL = 0;               //No scan
  ADCON3 = 0x1F02;          //ADCS=3 (min TAD for 10MHz is 3*TCY=300ns)
  ADCON2 = 0;               //Interrupt upon completion of one sample/convert
  ADCON1bits.ADON = 1;          //ADC on
}

int main(void)
{
   ADC_Init();              //Initialize the ADC
   PORTE = 0;                               //Set all of PORTE to 0
   TRISE = 0x0000;          //make these ports set to output

   int result = 0;              //variable used to hold the initial sensor reading after each motor step
   int tempResult = 0;      //used to find the difference between result and the most recent sensor
reading
   int pillDropped = 0;     //a boolean used to terminate the while loop once a pill has been
dropped
```

```
  while(pillDropped == 0)
  {
                ADCON1bits.SAMP = 1;                    //Start sampling (SAMP=1)
     while (!ADCON1bits.DONE){}                         //Wait for DONE bit in
ADCON1
     result = ADCBUF0;                          //Store result

     stepMotor();                          //Steps the motor 7.2 degrees

     for(delay2=0;delay2<1;delay2++){                   //enter a for loop that is used to
check the sensor
       for(delay=0;delay<20000;delay++){
         ADCON1bits.SAMP = 1;                           //Start sampling (SAMP=1)
         while (!ADCON1bits.DONE){}                     //Wait for DONE bit in ADCON1
                        tempResult = result - ADCBUF0;  //Find the difference between the
initial result and the most recent reading
                        if(tempResult < 0)
                          tempResult = tempResult*-1;   //If the difference is negative, change
the sign
         if(tempResult > 25)                            //is the difference is larger than 25, then a
pill was dropped
                        {
                           pillDropped = 1;
                        }
       }
     }
  }
```

```
  while (1) {}                          //endless loop used to put the processor in a
sleep-like state

  return 0;

}
```

# Appendix B

## Wi-Fi Transceiver Module

# MRF24WB0MA/MRF24WB0MB Data Sheet
# 2.4 GHz IEEE Std. 802.11b™

## Features:

- IEEE Std. 802.11-compliant RF Transceiver
- Serialized unique MAC address
- Data Rate: 1 and 2 Mbps
- IEEE Std. 802.11b/g/n compatible
- Small size: 21mm x 31mm 36-pin Surface Mount Module
- Integrated PCB antenna (MRF24WB0MA)
- External antenna option (MRF24WB0MB) with ultra miniature coaxial (U.FL) connector
- Range: up to 400m (1300 ft.)
- Easy integration into final product – accelerates product development, provides quicker time to market
- Radio regulation certification for United States (FCC), Canada (IC), Europe (ETSI) and Japan (ARIB)
- Wi-Fi® certified (WFA ID: WFA7150)
- Designed for use with Microchip microcontroller families (PIC18, PIC24, dsPIC33, and PIC32) with downloadable Microchip TCP/IP Stack

## Operational:

- Single operating voltage: 2.7V–3.6V (3.3V typical)
- Temperature Range: -20° C to +85° C extended commercial
- Simple, four-wire SPI interface with interrupt
- Low-current consumption:
  - RX mode – 85 mA (typical)
  - TX mode – 154 mA (+10 dBm typical)
  - Sleep – 250 µA (typical)
  - Hibernate – <0.1 µA (typical)

## RF/Analog Features:

- ISM Band 2.400–2.484 GHz operation
- 14 Channels selectable individually or domain-restricted
- DSSS Modulation
- Data Rate – 1000 kbps
- -91 dBm Typical sensitivity at 1 Mbps
- +10 dBm Typical output power with control
- Integrated low phase noise VCO, RF frequency synthesizer, PLL loop filter and PA
- Digital VCO and filter calibration
- Integrated RSSI ADC and I/Q DACs, RSSI readings available to host
- Balanced receiver and transmitter characteristics for low power consumption

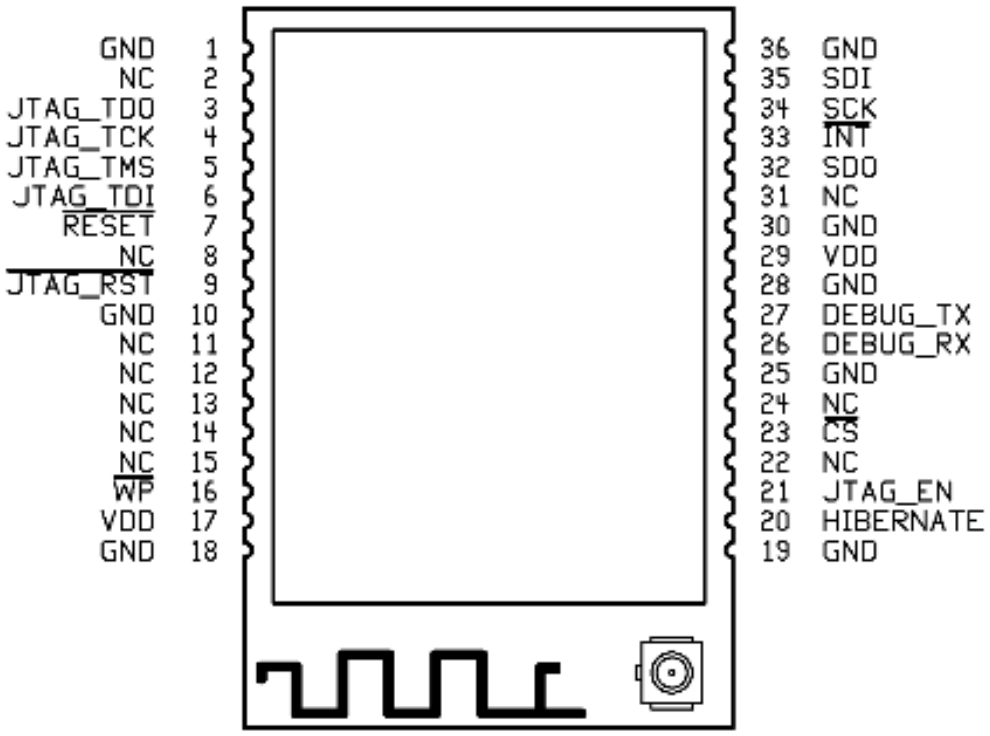
## MAC/Baseband Features:

- Hardware CSMA/CA access control, automatic ACK, and FCS creation and checking
- Automatic MAC packet retransmit
- Hardware Security Engine for AES and RC4-based ciphers
- Supports 802.1x, 802.1i security: WEP, WPA-PSK, and WPA-2-PSK.

## Applications:

- Utility and Smart Energy
  - Thermostats
  - Smart Meters
  - White Goods
  - HVAC
- Consumer Electronics
  - Remote Control
  - Internet Radio
  - Home Security
  - Toys
- Industrial Controls
  - Chemical Sensors
  - HVAC
  - Security Systems
  - M2M Communication
- Remote Device Management
  - Location and Asset Tracking
  - Automotive
  - Code Update
- Retail
  - POS Terminals
  - Wireless Price Tags
  - Digital Remote
- Medical, Fitness, and Health care
  - Glucose Meters
  - Fitness Equipment
  - Patient Asset Tracking

## Pin Diagram




**Note:** Antenna connector on MRF24WB0MB only.

## 1.0 DEVICES OVERVIEW

The MRF24WB0MA and MRF24WB0MB are low-power, 2.4 GHz, IEEE Std. 802.11-compliant, surface mount modules with all associated RF components – crystal oscillator, bypass and bias passives with integrated MAC, baseband, RF and power amplifier, and built-in hardware support for AES, and TKIP (WEP, WPA, WPA2 security). The integrated module design frees the designer from RF and antenna design tasks and regulatory compliance testing, ultimately providing quicker time to market.

The MRF24WB0MA module is approved for use with the integrated PCB meander antenna.

The MRF24WB0MB comes with an ultra miniature coaxial connector (U.FL) and is approved for use with a list of pre-certified antennas. See Section 2.8, External Antenna, for specific recommendations.

The MRF24WB0MA/MRF24WB0MB modules are designed to be used with Microchip's TCP/IP software stack. The software stack has an integrated driver that implements the API that is used in the modules for command and control, and for management and data packet traffic.

The Microchip TCP/IP software stack is available in the free *Microchip Application Libraries* download (including example applications and source code) from the Microchip web site, http://www.microchip.com/wireless.

The combination of the module and a PIC running the TCP/IP stack results in support for IEEE Standard 802.11 and IP services. This allows, the immediate implementation of a wireless web server.

The MRF24WB0MA/MRF24WB0MB modules have received regulatory approvals for modular devices in the United States (FCC), Canada (IC), and Europe (ETSI). The modular approval removes the need for expensive RF and antenna design, and allows the end user to place the modules inside a finished product and not require regulatory testing for an intentional radiator (RF transmitter). They also have Radio Type Approval Certification for Japan. See Section 3.0, Regulatory Approval, for the specific requirements that should be adhered to by the integrator.

### 1.1 Interface Description

The block diagram in Figure 1-1 represents a MRF24WB0MA/MRF24WB0MB module. It interfaces to Microchip PIC18, PIC24, dsPIC33, or PIC32 microcontrollers through a four-wire serial slave SPI interface – interrupt, hibernate, reset, power and ground signals. The module runs on a single supply voltage of nominally 3.3V. It also supports optional JTAG and serial debug for testability. The debug port operates at 3.3V and requires a level shifter for operation with RS-232 devices. Figure 1-2 shows a simplified example connection between a Microchip PIC MCU and the module. Table 1-1 lists the pin descriptions.

Data communications with the MRF24WB0MA/MRF24WB0MB are through the SPI interface that is detailed in Section 2.0, Circuit Description. The Microchip PIC microcontroller communicates with the module through a command API from within the Microchip TCP/IP stack. The command API is detailed in the Microchip TCP/IP stack online help that is included in the free *Microchip Application Libraries* download.

**TABLE 1-1: Pin Description**

| Pin | Symbol | Type | Description |
|---|---|---|---|
| 1 | GND | P | Ground |
| 2 | NC | NC | Do not connect |
| 3 | JTAGTDO | O | JTAG test data output |
| 4 | JTAGTCK | I: Constant(1) | JTAG clock input |
| 5 | JTAGTMS | I | JTAG mode input |
| 6 | JTAGTDI | I | JTAG test data input |
| 7 | $\overline{\text{RESET}}$ | I: Constant(1) | Module Reset input |
| 8 | NC | NC | Do not connect |
| 9 | $\overline{\text{JTAGRST}}$ | I | JTAG Reset input (optional; see Section 2.0, Circuit Description) |
| 10 | GND | P | Ground |
| 11 | NC | NC | Do not connect |
| 12 | NC | NC | Do not connect |
| 13 | NC | NC | Do not connect |
| 14 | NC | NC | Do not connect |
| 15 | NC | NC | Do not connect |
| 16 | $\overline{\text{WP}}$(2) | I | Write protect (this pin is used to enable FLASH update) |
| 17 | VDD | P | Power |
| 18 | GND | P | Ground |
| 19 | GND | P | Ground |
| 20 | HIBERNATE | I | Hibernate mode enable (high input will disable the module) |
| 21 | JTAGEN | I | JTAG test enable |
| 22 | NC | NC | Do not connect |
| 23 | $\overline{\text{CS}}$ | I: Constant(1) | SPI Chip Select input, constant drive or pull-up required |
| 24 | NC | NC | Do not connect |
| 25 | GND | P | Ground |
| 26 | DEBUGRX | I | Serial debug port input (see Section 2.0, Circuit Description) |
| 27 | DEBUGTX | O | Serial debug port output (see Section 2.0, Circuit Description) |
| 28 | GND | P | Ground |
| 29 | VDD | P | Power |
| 30 | GND | P | Ground |
| 31 | NC | NC | Do not connect |
| 32 | SDO | O | SPI data out |
| 33 | $\overline{\text{INT}}$ | O | Interrupt output (open drain – requires a pull-up) |
| 34 | SCK | I | SPI clock input |
| 35 | SDI | I | SPI data in |
| 36 | GND | P | Ground |

**Legend:** Pin type abbreviation: P = Power input, I = Input, O = Output, NC = Do Not Connect

**Note 1:** Signals of Type "I: Constant" must either be constantly driven by the host or have a pull-up or pull-down (in case the host is likely to tri-state the signal during power down modes). The constant drive is used to ensure defined operation of the part and to minimize leakage current during low power modes.

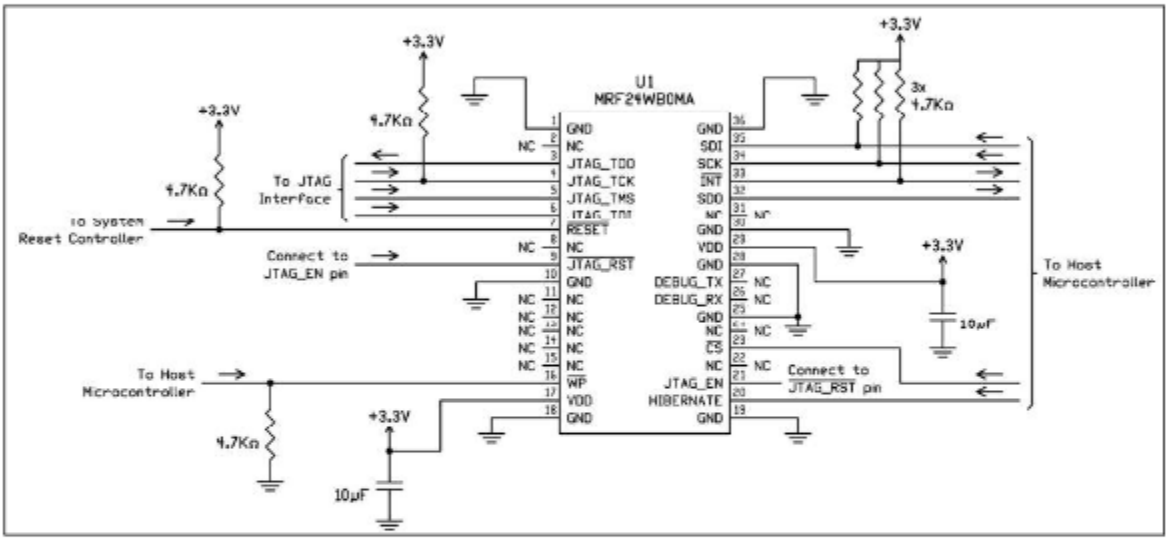
**2:** $\overline{\text{WP}}$ is used as write-protect for the internal module SPI Flash. For production use, this pin should be pulled low. This pin can be controlled by the host microcontroller to enable in field Flash updates.

## 2.0 CIRCUIT DESCRIPTION

The MRF24WB0MA/MRF24WB0MB interfaces to Microchip PIC18, PIC24, dsPIC33, and PIC32 microprocessors with a minimal of external components through digital-only connections. This section details use of the module, starting with an example host connection as shown in Figure 2-1.

### 2.1 Schematic

FIGURE 2-1: MRF24WB0MA/MRF24WB0MB EXAMPLE APPLICATION SCHEMATIC




### 2.2 Power-On Sequence

The internal regulators for the digital and analog core power supplies are disabled by driving the HIBERNATE pin high. Figure 2-2 shows the power up sequence for the MRF24WB0MA/MRF24WB0MB.

There is an internal Power-on-Reset (POR) circuit which keeps the module in reset until VDD is within specification. The Hibernate and Reset signals are also used to control startup. In Figure 2-2, section A is controlled by the internal POR and section B is an allowance for the SPI bus to stabilize when the module supplies are enabled. Once Hibernate is disabled, the host software provides 1mS of startup to allow the SPI to stabilize. This time is pre-programmed into the host driver, and may need to be increased if insufficient initial drive current is not provided to the MRF24WB0M module. Section C is the driver controlled release from Reset period. This takes approximately 300 mS and is monitored by the stack driver. No additional time needs to be provided by user software for startup.

## 2.3 Power States

The MRF24WB0MA/MRF24WB0MB has several power states. These are Hibernate, Sleep and Active (two sub-states), as shown in Figure 2-3. The selection of power state directly affects system behavior, and overall power consumption or battery life. There is also a "Standby" state that is not user-controlled.

### 2.3.1 HIBERNATE STATE

An "Off" state is defined as no power applied to the device. The Hibernate mode is the closest to controlled off that the module can approach. It is controlled through the HIBERNATE pin (high input puts the module into Hibernate). When in Hibernate, the module only consumes leakage current, but does not maintain state. Hibernate has to be fully controlled by the PIC MCU and requires the TCP/IP stack to restart on an awake.

The module contains about 70µF of internal bulk capacitance. Supplies should be provisioned to supply sufficient charge on release of hibernate for desired start time or sufficient delay must be provided in software after hibernate release and before releasing reset.

This state provides the best battery life for embedded products. Entering Hibernate for intervals of less than 30 seconds is not likely to save power. Battery life expectation can be more than a year for devices operating on AA cells that would be in Hibernate except to wake up every hour for a small data transfer (<500 Bytes).

### 2.3.2 SLEEP STATE

The Sleep state is a low power dynamic state that automatically implements the 802.11 Power Save feature. In this mode, if enabled, the module will enter Power Save mode when all activity is complete.

The module will wake autonomously to any PIC intervention so it can check DTIM beacons from the Access Point. If any traffic is listed as queued for the module, then it will awaken and get the data from the Access Point on the next possible opportunity. When data is acquired, the module will interrupt the PIC microcontroller on a normal "data available" indication. If no data is available on a DTIM check, the module reenters the Power Save state until the next DTIM. The DTIM interval is programmed at the Access Point. This state can provide "as if on" behavior of the radio with a significant power savings versus "always on". The battery life expectation of this mode is several days to several weeks. This mode is characterized by a very low latency (as low as 200 mS) to begin data transfer from the low power state.

### 2.3.3 ACTIVE STATE

The Active state is identified as one of two states where the radio circuitry is fully on. The two active states are the Receive state (RX ON) and the Transmit state (TX ON).

### 2.3.4 STANDBY STATE

The Standby state is not user-controlled but is noted as it helps identify and track certain operations of the module during power tracing.

**TABLE 2-1: MRF24WB0MA/MRF24WB0MB POWER STATE DEFINITIONS**

| State | VDD | $\overline{CS}$ | Description |
|---|---|---|---|
| Off | 0V | 0V | Power is completely disconnected |
| Hibernate | 3.3V | 3.3V | All internal power regulators are OFF – enabled by HIBERNATE pin |
| Sleep | 3.3V | 0V | Enabled by TCP/IP driver |
| RX ON | 3.3V | 0V | Receive circuits are on and receiving |
| TX ON | 3.3V | 0V | Transmit circuits are on and transmitting |
| Standby | 3.3V | 0V | State machine transition state only – not user controlled |

## 4.0 ELECTRICAL CHARACTERISTICS

**TABLE 4-1: DIGITAL ELECTRICAL CHARACTERISTICS (NOMINAL CONDITIONS: 25C, $V_{DD}$ = 3.3V)**

| Parameters | Min | Typ | Max | Units |
|---|---|---|---|---|
| $V_{IL}$ (Input low voltage) | -0.3 | — | 0.8 | V |
| $V_{IH}$ (Input high voltage) | 2 | — | 5.5 | V |
| $V_{OL}$ (Output low voltage) | — | — | 0.4 | V |
| $V_{OH}$ (Output high voltage) | 2.4 | — | — | V |
| $I_{OL}$ (Output low level current at $V_{OL}$ Max) | — | 8.5 | — | mA |
| $I_{OH}$ (Output high level current at $V_{OH}$ Min) | — | 15.4 | — | mA |

**TABLE 4-2: ABSOLUTE MAXIMUM RATINGS(1)**

| Parameters | Min | Max | Notes |
|---|---|---|---|
| Storage Temperature | -40C | +125C | — |
| $V_{DD}$ | 0V | 4.2V for 0.5mSec | $V_{DD}$ above this level and duration will disable Radio |
| $V_{IN}$ on SDI, $\overline{CS}$, SCK | -0.3V | 5.5V | — |

**Note 1:** Listed Absolute Maximum Ratings are not meant for functional operation. Operation at these levels is not guaranteed, and may reduce the operating life of the component.

**TABLE 4-3: RECOMMENDED OPERATING CONDITIONS**

| Parameters | Min | Typ | Max | Units |
|---|---|---|---|---|
| Ambient Temperature(2) | -20 | — | +85 | Degrees Celsius |
| $V_{DD}$ – for FCC and IC | 2.70 | 3.3 | 3.63(1) | Volts |

**Note 1:** While 3.63V is the maximum operating voltage, the module will detect an overvoltage condition at 4.2V and disable the RF Transmit function after 0.5 ms. This is an RF certification requirement pertaining to disabling transmission in unforeseen overvoltage conditions.

**2:** Ambient temperature for industrial part number is minimum -40C to maximum +85C. Contact Microchip Sales for industrial temperature parts.

TABLE 4-4: CURRENT CONSUMPTION[3] (NOMINAL CONDITIONS: 25C, VDD = 3.3V)

| Parameters | Min | Typ | Max | Units |
|---|---|---|---|---|
| IDD, Hibernate = 3.3V | — | 0.1 | — | µA |
| IDD, Sleep (software enabled) | — | 250[1] | — | µA |
| IDD, Standby (transitional state) | — | 10 | — | mA |
| IDD core[2], RX on, Receive @-83dBm with 2Mbps modulated signal at antenna port | — | 85 | — | mA |
| IDD core, TX on, +0 dBm | — | 115 | — | mA |
| IDD core, TX on, +10 dBm | — | 154 | — | mA |

**Note 1:** Sleep current is current consumed during periods of "standby" between DTIM beacons. The module will awake 2 mS before a DTIM and turn on its receiver, and possibly its transmitter (if data is available for it).

**2:** IDD core is current consumed by the part not including the I/O consumption of the SPI port.

**3:** Current Consumption values represent Typical Peak currents, and the measured current conditions were done with 85% duty cycle modulated signal. Wi-Fi applications typically operate at less than 85% TX duty cycle. TX current is dependent on such criteria as transmit power setting, and transmit data rate and bandwidth being used. RX current is affected by connection distance.

TABLE 4-5: RECEIVER AC CHARACTERISTICS[1]

| Parameters | Min | Typ | Max | Units |
|---|---|---|---|---|
| Flo | 2412 | — | 2484 | MHz |
| RX Min Input Level Sensitivity, 1Mbps, 8% PER | — | -91 | — | dBm |
| RX Min Input Level Sensitivity, 2Mbps, 8% PER | — | -88 | — | dBm |
| RX Max Input Level (Power), 1Mbps, 8% PER | — | -4 | — | dBm |
| RX Max Input Level (Power), 2Mbps, 8% PER | — | -4 | — | dBm |

**Note 1:** Nominal conditions: 25C, VDD = 3.3V, Flo = 2437 MHz, measurements at antenna port.

TABLE 4-6: TRANSMITTER AC CHARACTERISTICS[1]

| Parameters | Min | Typ | Max | Units |
|---|---|---|---|---|
| Flo | 2412 | — | 2484 | MHz |
| Average Pout (transmit spectrum mask compliant) | — | +10 | — | dBm |
| Average Pout gain step resolution from +5 to +10dBm | — | 0.5 | — | dB |
| Average Pout gain step resolution from -5 to +5dbm | — | 1.0 | — | dB |
| Average Pout settled variation | -0.5 | — | 0.5 | dB |

**Note 1:** Nominal conditions: 25C, VDD = 3.3V, Flo = 2437 MHz, 2 Mbps. modulated signal measured at antenna port.

# Appendix C

## LCD Screen

# HD44780U (LCD-II)

(Dot Matrix Liquid Crystal Display Controller/Driver)

HITACHI

ADE-207-272(Z)
'99.9
Rev. 0.0

## Description

The HD44780U dot-matrix liquid crystal display controller and driver LSI displays alphanumerics, Japanese kana characters, and symbols. It can be configured to drive a dot-matrix liquid crystal display under the control of a 4- or 8-bit microprocessor. Since all the functions such as display RAM, character generator, and liquid crystal driver, required for driving a dot-matrix liquid crystal display are internally provided on one chip, a minimal system can be interfaced with this controller/driver.

A single HD44780U can display up to one 8-character line or two 8-character lines.

The HD44780U has pin function compatibility with the HD44780S which allows the user to easily replace an LCD-II with an HD44780U. The HD44780U character generator ROM is extended to generate 208 5 × 8 dot character fonts and 32 5 × 10 dot character fonts for a total of 240 different character fonts.

The low power supply (2.7V to 5.5V) of the HD44780U is suitable for any portable battery-driven product requiring low power dissipation.

## Features

- 5 × 8 and 5 × 10 dot matrix possible
- Low power operation support:
  — 2.7 to 5.5V
- Wide range of liquid crystal display driver power
  — 3.0 to 11V
- Liquid crystal drive waveform
  — A (One line frequency AC waveform)
- Correspond to high speed MPU bus interface
  — 2 MHz (when $V_{CC}$ = 5V)
- 4-bit or 8-bit MPU interface enabled
- 80 × 8-bit display RAM (80 characters max.)
- 9,920-bit character generator ROM for a total of 240 character fonts
  — 208 character fonts (5 × 8 dot)
  — 32 character fonts (5 × 10 dot)

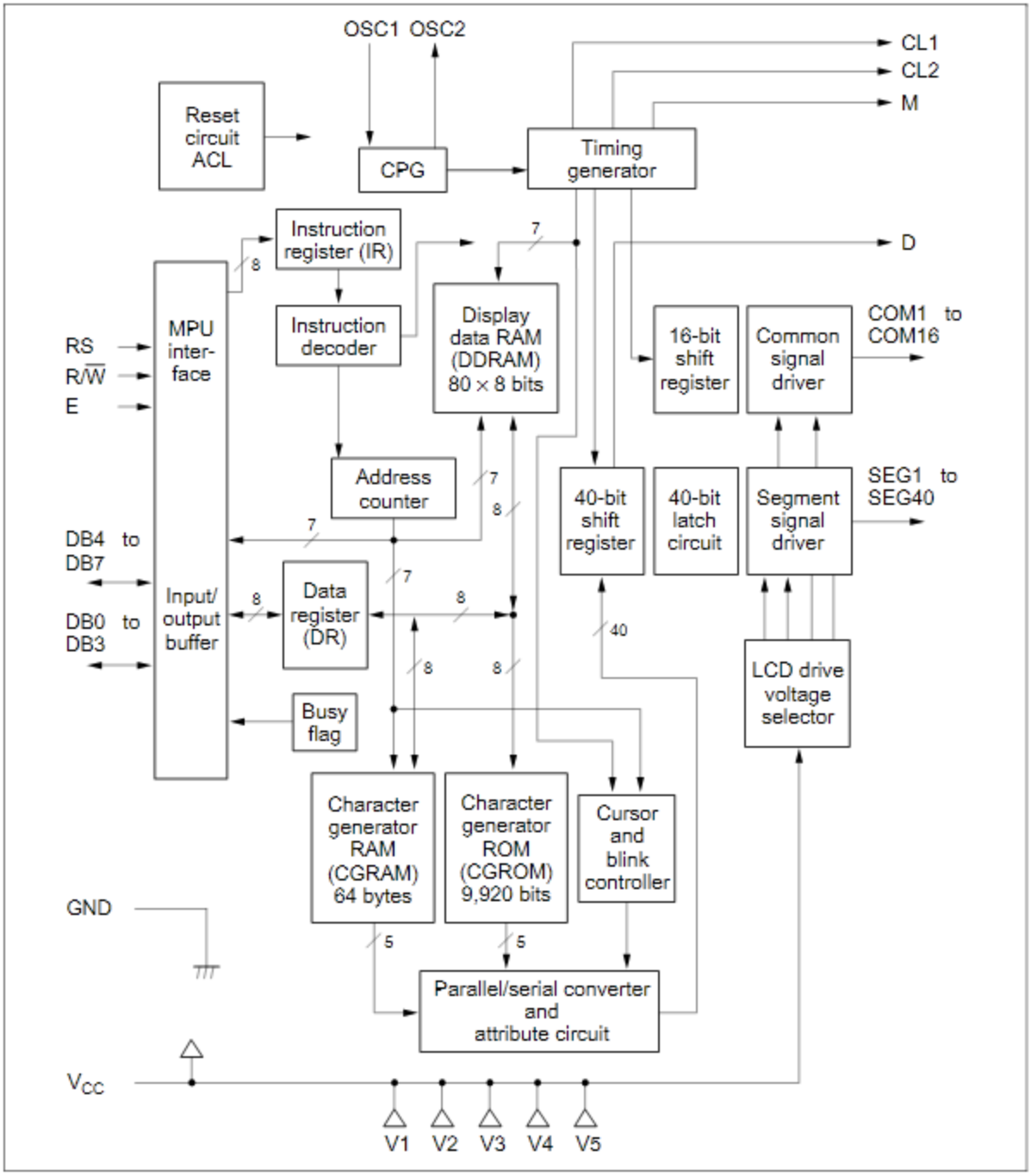
- 64 × 8-bit character generator RAM
  - — 8 character fonts (5 × 8 dot)
  - — 4 character fonts (5 × 10 dot)
- 16-common × 40-segment liquid crystal display driver
- Programmable duty cycles
  - — 1/8 for one line of 5 × 8 dots with cursor
  - — 1/11 for one line of 5 × 10 dots with cursor
  - — 1/16 for two lines of 5 × 8 dots with cursor
- Wide range of instruction functions:
  - — Display clear, cursor home, display on/off, cursor on/off, display character blink, cursor shift, display shift
- Pin function compatibility with HD44780S
- Automatic reset circuit that initializes the controller/driver after power on
- Internal oscillator with external resistors
- Low power consumption

## Ordering Information

| Type No. | Package | CGROM |
|---|---|---|
| HD44780UA00FS<br>HCD44780UA00<br>HD44780UA00TF | FP-80B<br>Chip<br>TFP-80F | Japanese standard font |
| HD44780UA02FS<br>HCD44780UA02<br>HD44780UA02TF | FP-80B<br>Chip<br>TFP-80F | European standard font |
| HD44780UBxxFS<br>HCD44780UBxx<br>HD44780UBxxTF | FP-80B<br>Chip<br>TFP-80F | Custom font |

Note: xx: ROM code No.

## HD44780U Block Diagram



## Pin Functions

| Signal | No. of Lines | I/O | Device Interfaced with | Function |
|---|---|---|---|---|
| RS | 1 | I | MPU | Selects registers.<br>0: Instruction register (for write) Busy flag: address counter (for read)<br>1: Data register (for write and read) |
| R/$\overline{W}$ | 1 | I | MPU | Selects read or write.<br>0: Write<br>1: Read |
| E | 1 | I | MPU | Starts data read/write. |
| DB4 to DB7 | 4 | I/O | MPU | Four high order bidirectional tristate data bus pins. Used for data transfer and receive between the MPU and the HD44780U. DB7 can be used as a busy flag. |
| DB0 to DB3 | 4 | I/O | MPU | Four low order bidirectional tristate data bus pins. Used for data transfer and receive between the MPU and the HD44780U.<br>These pins are not used during 4-bit operation. |
| CL1 | 1 | O | Extension driver | Clock to latch serial data D sent to the extension driver |
| CL2 | 1 | O | Extension driver | Clock to shift serial data D |
| M | 1 | O | Extension driver | Switch signal for converting the liquid crystal drive waveform to AC |
| D | 1 | O | Extension driver | Character pattern data corresponding to each segment signal |
| COM1 to COM16 | 16 | O | LCD | Common signals that are not used are changed to non-selection waveforms. COM9 to COM16 are non-selection waveforms at 1/8 duty factor and COM12 to COM16 are non-selection waveforms at 1/11 duty factor. |
| SEG1 to SEG40 | 40 | O | LCD | Segment signals |
| V1 to V5 | 5 | — | Power supply | Power supply for LCD drive<br>$V_{cc}$ –V5 = 11 V (max) |
| $V_{cc}$, GND | 2 | — | Power supply | $V_{cc}$: 2.7V to 5.5V, GND: 0V |
| OSC1, OSC2 | 2 | — | Oscillation resistor clock | When crystal oscillation is performed, a resistor must be connected externally. When the pin input is an external clock, it must be input to OSC1. |

```
#include <p30f6015.h>
#include <string.h>
#include <stdlib.h>

void lcdDelay()
{
      int delay = 0;
      int delay2 = 0;

      for(delay2=0;delay2<1;delay2++){
    for(delay=0;delay<2500;delay++){}
    }
}

//this function is used to clear the display
void clearLCD()
{
      //Set the command to clear the display
      PORTE = 0x0001;
      PORTF = 0X0000;

      //Send the command
      PORTF = 0x0004;

      lcdDelay();

      PORTF = 0x0000;

      lcdDelay();
}

//this function is used to turn on the display and show a
blinking cursor
void initLCD()
{
      //Set the command to turn on all 4 lines
      PORTE = 0x0038;
      PORTF = 0X0000;

      //Send the command
      PORTF = 0x0004;

      lcdDelay();

      //Set the command to turn on the display and show
      //a blinking cursor
      PORTE = 0x000F;

      //Send the command
      PORTF = 0x0004;

      lcdDelay();

      PORTF = 0x0000;

      lcdDelay();

      //clearLCD();
}

void goBack()
{
      //Set the command to turn on all 4 lines
      PORTE = 0x0010;
      PORTF = 0X0000;

      //Send the command
      PORTF = 0x0004;

      lcdDelay();

      PORTF = 0x0000;

      lcdDelay();
}

//this function is used to convert a given character
//and print it to the LCD
void printCharacter(char character)
{
      int converted_character = character;
      //Set the command to print the character
      PORTE = converted_character;
      PORTF = 0x0001;

      //Send the command
      PORTF = 0x0005;

      lcdDelay();

      PORTF = 0x0001;

      lcdDelay();
}

void printString(char message[], int length)
{
      int index;
      for(index=0; index<length; index++)
      {
            printCharacter(message[index]);
      }
}
void printInteger(int input)
{

      int firstI = (input % 10) + 48;
      input = input/10;
      int secondI = (input % 10) + 48;
      input = input/10;
      int thirdI = (input % 10) + 48;
      input = input/10;
      int fourthI = (input % 10) + 48;

      char first = firstI;
      char second = secondI;
      char third = thirdI;
      char fourth = fourthI;

      printCharacter(fourth);
      printCharacter(third);
      printCharacter(second);
      printCharacter(first);
}

/*
EOF
*/
```

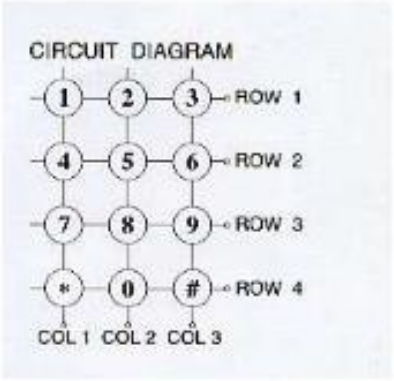
# Appendix D

## Keypad

**General Specification**

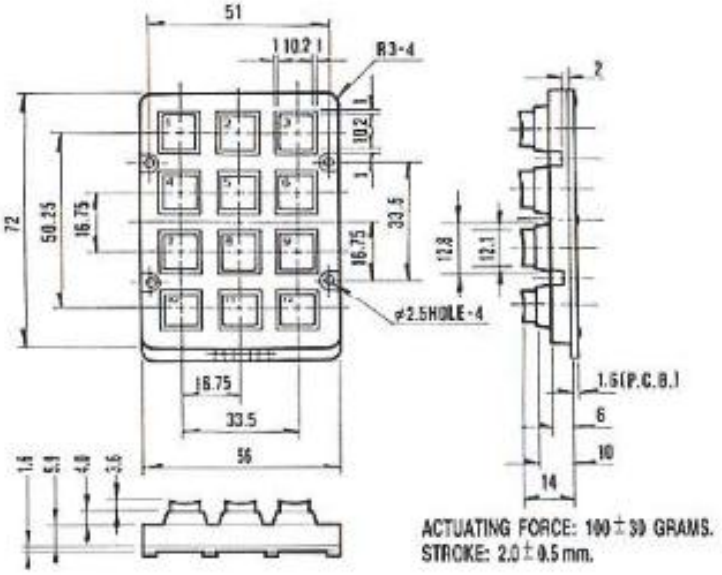
- Contact rating:20mA,24VDC
- Contact resistance:200 ohm max
- Life:1,000,000 cycles per key
- Operating Temperature: -20□ to +60□
- Storage Temperature: -40□ to +65□

**Standard Matrix Circuit Diagram**



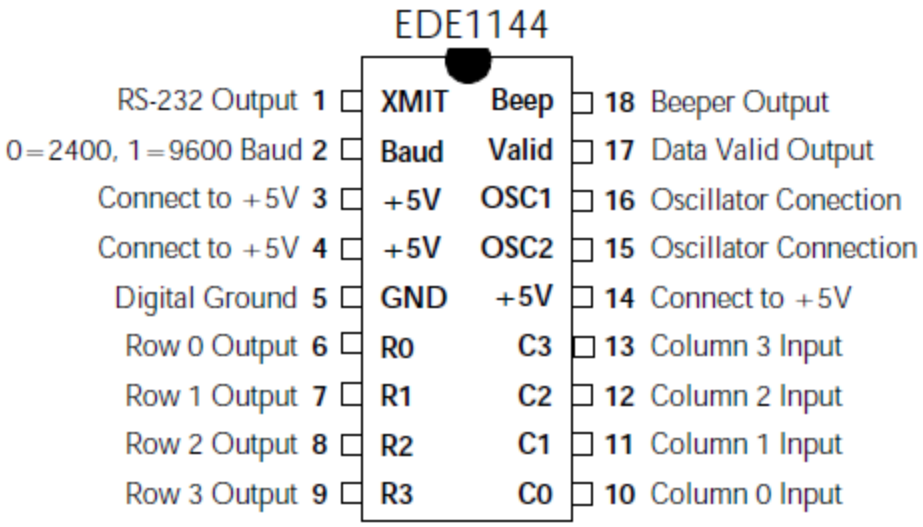

**AK-207**

| OUTPUT ARRANGEMENT | |
|---|---|
| OUTPUT PIN NO. | SYMBOL |
| 1 | COL 2 |
| 2 | ROW 1 |
| 3 | COL 1 |
| 4 | ROW 4 |
| 5 | COL 3 |
| 6 | ROW 3 |
| 7 | ROW 2 |



# EDE1144 Keypad Encoder IC

*4 x 4 Matrix Keypad Encoder IC*




***Functionality & Feature Set:***

- ***Automatic key repeat after delay***
- ***Contact debouncing***
- ***Keybeep provides tactile feedback to operator***
- ***Electrically quiet (reduced EMI) keypad scanning***
- ***Serial / Parallel outputs available***
- ***Data Valid output signal for interrupt activation***
- ***2400/ 9600 serial Baud rates***
- ***Available in 18 pin DIP or SOIC packages***
- ***Interfaces to any microcontroller or microprocessor***
- ***Cost effective for OEM applications***

The EDE1144 Keypad Encoder IC is designed to interface a matrix-type 4 row x 4 column (16 key or less) keypad to a microcontroller or other host processor. A one-wire serial or four-wire parallel interface returns the keypress data and can be used in conjunction with a 'data valid' signal for polled or interrupt-driven applications. The EDE1144 provides enhanced keypad features such as contact debouncing and key auto-repeat in an easy-to-use package that will lower software overhead in the host microcontroller and reduce the I/O pin requirements from eight to one, frequently resulting in the use of a less costly host microcontroller in your design.

In addition, the EDE1144 is electrically quiet. Many keypad encoders continually scan the keypad, radiating EMI noise from the wires leading to the keypad (resulting in trouble during emissions testing & final product certification & approval). The EDE1144 reduces this problem by monitoring the keypad with unchanging signals, and then scanning only once each time a keypress is detected.

## PIN DEFINITIONS

### *Keypad Connection Pins:*

(**R0**) Row 0 / Data 0 Output (Pin 6)..... Multiplexed Keypad Row 0, Host System Data Input 0

(**R1**) Row 1 / Data 1 Output (Pin 7)..... Multiplexed Keypad Row 1, Host System Data Input 1

(**R2**) Row 2 / Data 2 Output (Pin 8)..... Multiplexed Keypad Row 2, Host System Data Input 2

(**R3**) Row 3 / Data 3 Output (Pin 9)..... Multiplexed Keypad Row 3, Host System Data Input 3

(**C0**) Column 0 Input (Pin 10)..... Multiplexed Keypad Column 0 (through 330 Ω resistor)

(**C1**) Column 1 Input (Pin 11)..... Multiplexed Keypad Column 1 (through 330 Ω resistor)

(**C2**) Column 2 Input (Pin 12)..... Multiplexed Keypad Column 2 (through 330 Ω resistor)

(**C3**) Column 3 Input (Pin 13)..... Multiplexed Keypad Column 3 (through 330 Ω resistor)

### *Control & Data Pins:*

**Baud** (Pin 2)..... Baud Rate Selection; 0=2400, 1=9600

**XMIT** (Pin 1)..... Serial Data Output (N-8-1); RS232 (TTL/CMOS Voltages)

**Valid** (Pin 17)..... Data Valid Signal / Interrupt: Parallel data valid when low

**Beep** (Pin 18)..... Modulated Output Signal: Oscillates on keypress or repeat

### *Clock / Power Pins:*

**OSC1** (Pin 16)..... One pin of 4MHz parallel-cut crystal or resonator, or a direct TTL clock input

**OSC2** (Pin 17)..... Other pin of 4MHz parallel-cut crystal or resonator, or leave floating if OSC1 driven with a TTL clock input

**+5V** (Pins 3,4,14)..... Connect to +5V DC

**GND** (Pin 5)..... Connect to 0V DC (Ground)

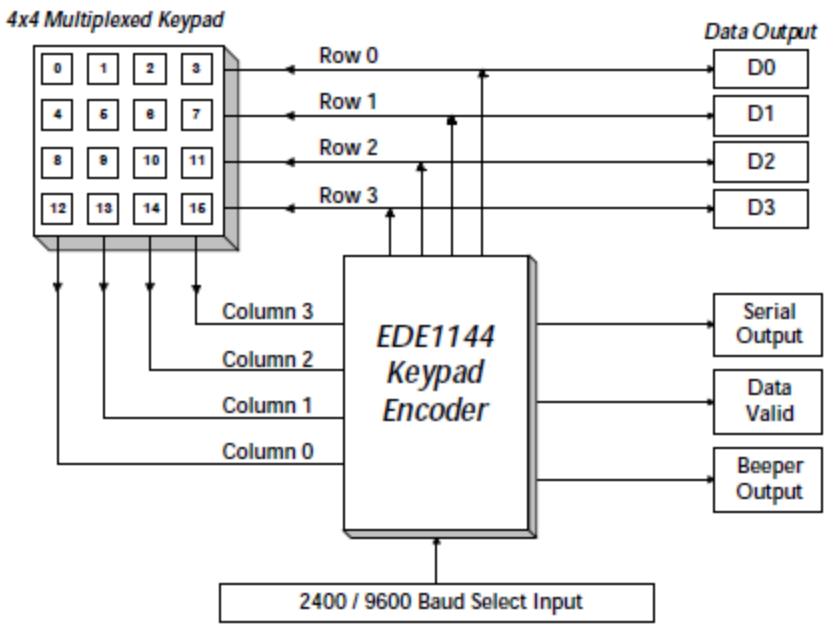



*Figure One: Connection Block Diagram*

As illustrated by Figure One, the EDE1144 resides between the keypad and host microcontroller/ processor. The host microcontroller receives keypress data via either the four parallel data outputs (D0-D3, Pins 6-9) or the Serial Data Output (Pin 1). The Data Valid signal (Pin 17) is activated upon keypress (and upon each key repeat cycle if key is held). The Data Valid signal is activated prior to transmission of the serial data to allow polled (software-UART) style host serial systems such as the BASIC Stamp™ or a microcontroller without a hardware UART to enter the serial receive routine and receive the keypress data without needing to continually wait for the start bit. Note that the data outputs to the host microcontroller reside on the row output pins (Pins 6-9), therefore parallel-output data should only be read while the Data Valid (Pin 17) signal is active (low). Upon powerup, the four data output pins will be high, and will remain high except when a key is pressed.

The following table illustrates the data values returned by the serial and parallel outputs of the EDE144 upon each keypress. Note that the serial values are increased (by Hexadecimal 30 ($30) for 0-9 and Hex $37 for 10-15) to correspond to the ASCII equivalent (0-9,A-F) of the BCD (binary-coded decimal) value on the parallel outputs.

| Key: | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| RS-232: | $30 ('0') | $31 ('1') | $32 ('2') | $33 ('3') | $34 ('4') | $35 ('5') | $36 ('6') | $37 ('7') |
| D3..D0: | 0000 | 0001 | 0010 | 0011 | 0100 | 0101 | 0110 | 0111 |

| Key: | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|
| RS-232: | $38 ('8') | $39 ('9') | $41 ('A') | $42 ('B') | $43 ('C') | $44 ('D') | $45 ('E') | $46 ('F') |
| D3..D0: | 1000 | 1001 | 1010 | 1011 | 1100 | 1101 | 1110 | 1111 |

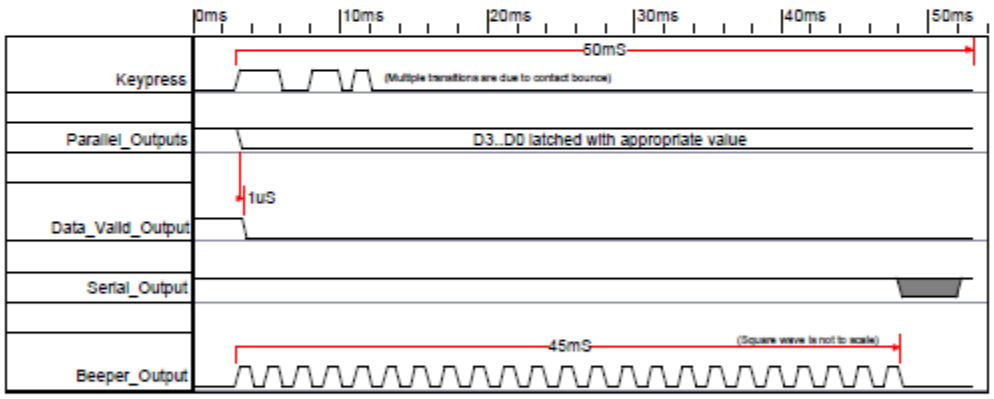
*Table One: Keynumber vs. Output Data*

## OVERVIEW OF OPERATION

Table One of the previous page illustrates the data that is output upon each keypress. The following sequence is initiated upon each keypress, and is repeated if the key is held:

1. ***Keypress is detected***
2. ***One scan cycle is performed***
3. ***Parallel Outputs (D3..D0) are latched with the appropriate value***
4. ***Data Valid signal is activated (pulled low)***
5. ***Beeper (1KHz square wave) is activated for 45mS***
6. ***Serial data is transmitted***

This entire cycle takes 50mS (regardless of Baud rate selected). If a key is held longer than the autorepeat delay of 660 mS, the cycle is repeated again at a rate of 5 times per second. The following timing diagram illustrates the above sequence:




Once a key is pressed, any additional closures (bounce) of that contact, or of any other contacts are ignored for 50mS, during which several signals are output by the EDE1144. First, the parallel outputs D0..D3 (Pins 6-9) are latched with the appropriate keypress value. One microsecond later, the Data Valid Output (Pin 17) goes low, indicating that there is valid data on the parallel output pins. Following this, the Beeper Output (Pin 18) pulse stream is generated for 45mS, providing auditory confirmation to the keypad operator that a key has been pressed. Finally, the RS-232 Output (Pin 1) transmits the keypress data at the Baud rate selected by the Baud rate input select (Pin 2). After this, a variable (determined by Baud rate chosen) delay period is waited to make the entire process to last precisely 50mS.

If a key is held longer that the autorepeat delay of 660mS, the outputs are cleared and this entire process is repeated every 204mS until the key is released by the operator.

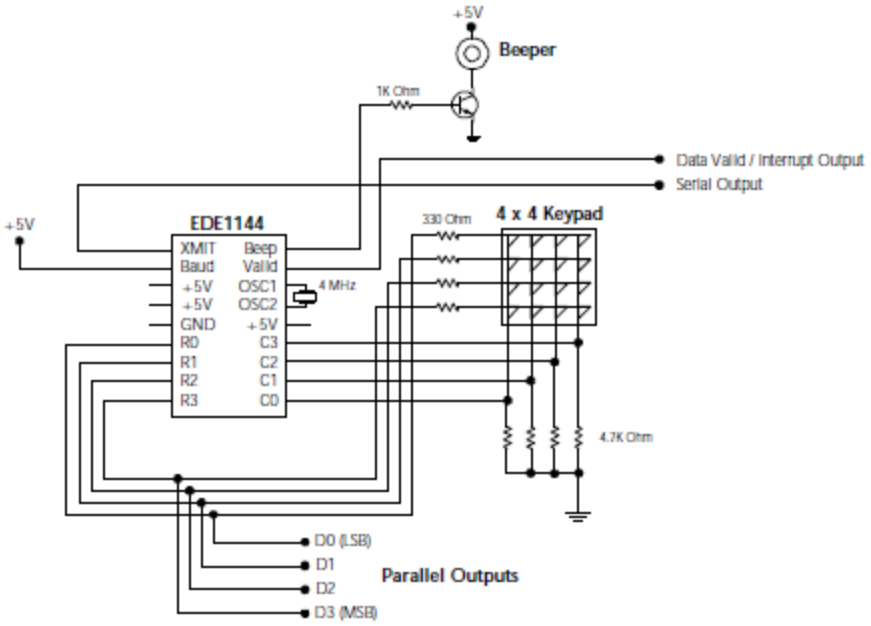



*Figure Two: Schematic of Keypad Connection*

Figure Two illustrates a typical connection of a 4x4 keypad to the EDE1144. Note that R0-R3 (Pins 6-9) are connected to the keypad rows through 330 Ohm resistors. They are present to prevent a short circuit during the scan cycle in case more that one key is being held at a time, and they can also help to lower radiated emissions from the keypad wires. The 4.7K Ohm resistors on the keypad columns are pulldowns to prevent the EDE1144 column inputs from floating or oscillating. Pulldowns should be present on all four column inputs (C0..C3) regardless of the keypad size or configuration being used. *Note: Power and Ground connections have been omitted from the EDE1144 hookup shown in Figure Two to simplify the illustration. They must be connected in actual operation. Also, when using a 4MHz resonator with internal capacitors, the third (center) pin should be connected to ground.*

## PARALLEL DATA CONNECTION

To read data from the EDE1144 in a parallel format the host microcontroller will input from the four data inputs D0,D1,D2, & D3, which also serve as the row drive signal pins R0,R1,R2, & R3 (see Figure Two). While the EDE1144 is waiting for a keypress, it will hold these lines at 1111 (all high). Once a key is pressed, the data output pins will toggle while the keypad is scanned so that the EDE1144 can determine which key was pressed. Then, the appropriate data value (see Table One) will be output onto the data outputs (via the row output pins), and the Data Valid Output (Pin 17) will go low. This pin will stay low for 50 mS, during which the Data Output pins will hold the keypress data. The keypress data should be sampled during this 50mS window.

Both the Parallel & Serial Data outputs are activated on each keypress (and autorepeat cycle); designers using the parallel data outputs can ignore the serial data output (and vice versa - designers using the serial data output can ignore the parallel data output).

```
/*    Ethan Lilly
      This program will allow for characters to be displayed on an
LCD screen by pressing
      the appropriate keys on a keypad
*/

#include <p30f6015.h>
#include <string.h>
#include <stdlib.h>
#include "lcd.h"

/* Macros for Configuration Fuse Registers (copied from device
header file):*/
_FOSC(CSW_FSCM_OFF & FRC & XT_PLL8);  /* Set up for Crystal
multiplied by 8x PLL */
_FWDT(WDT_OFF);                 /* Turn off the Watch-Dog Timer.
*/
//_FBORPOR(MCLR_EN & PWRT_OFF);   /* Enable MCLR reset pin and
turn off the power-up timers. */

/* Global Variables and Functions */
void INTx_IO_Init(void);
void __attribute__((__interrupt__)) _INT0Interrupt(void); /
*Declare external interrupt ISRs*/
void initTimer();

//this two dimensional array will allow me to traverse through
the characters when a button is
//pushed several times in a row
char keys[10][12] = {{'1', '7', '4', '*',
                      '3', '9', '6', '#',
                      '2', '8', '5', '0'},
                      {'!', 'p', 'g', '\0',
                       'd', 'w', 'm', '\0',
                       'a', 't', 'j', ' '},
                      {'_', 'q', 'h', '\0',
                       'e', 'x', 'n', '\0',
                       'b', 'u', 'k', '\0'},
                      {'#', 'r', 'i', '\0',
                       'f', 'y', 'o', '\0',
                       'c', 'v', 'l', '\0'},
                      {'@', 's', 'G', '\0',
                       'D', 'z', 'M', '\0',
                       'A', 'T', 'J', '\0'},
                      {'$', 'P', 'H', '\0',
                       'E', 'W', 'N', '\0',
                       'B', 'U', 'K', '\0'},
                      {'%', 'Q', 'I', '\0',
                       'F', 'X', 'O', '\0',
                       'C', 'V', 'L', '\0'},
                      {'&', 'R', '\0', '\0',
                       '\0', 'Y', '\0', '\0',
                       '\0', '\0', '\0', '\0'},
                      {'*', 'S', '\0', '\0',
                       '\0', 'Z', '\0', '\0',
                       '\0', '\0', '\0', '\0'},
                        {'\0', '\0', '\0', '\0',
                       '\0', '\0', '\0', '\0',
                       '\0', '\0', '\0', '\0'}};

int buffer = 0;
int repeat = 0;
int inputCount = 0;
int lastPressed = -1;
char input[33] = "\0";
```

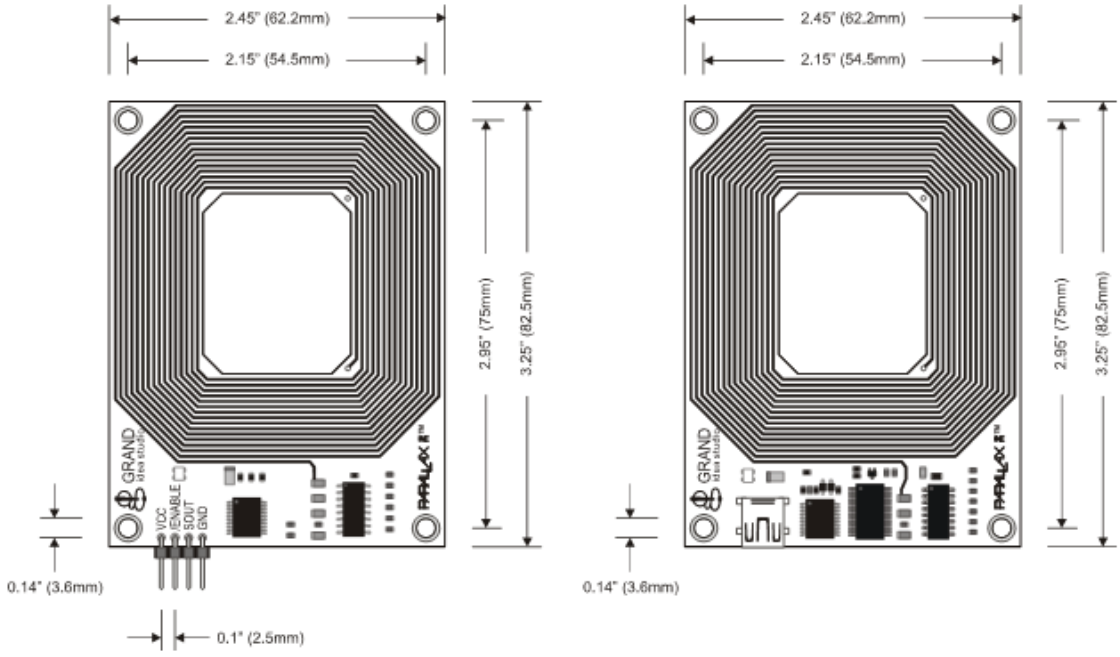
```
int main()
{
      PORTE = 0;                    //Set all of PORTE to 0
     TRISE = 0x0000;              //make these ports set to output
      PORTB = 0;                    //Set all of PORTE to 0
     TRISB = 0x0000;              //make these ports set to output
      PORTD = 0;                    //Set all of PORTE to 0
     TRISD = 0x000F;              //make these ports set to output

      INTx_IO_Init();

      initLCD();

      while(1)
      {
           //infinite loop to make the processor stay idle while
waiting for interrupts
      }


      return 0;
}

/*
Function:
INTx_IO_Init() sets up the INT0 pin.
*/
void INTx_IO_Init(void)
{
        INTCON2 = 0x0001;       /*Setup INT1, INT2, INT3 & INT4
pins to interupt */
                                /*on falling edge and set up INT0
pin to interupt */
                                /*on rising edge */
           INTCON1 = 0x0000;

        IFS0bits.INT0IF = 0;    /*Reset INT0 interrupt flag */
           IEC0bits.INT0IE = 1;  /*Enable INT0 interrupt*/
}

/*
_INT0Interrupt() is the INT0 interrupt service routine (ISR).
The routine must have global scope in order to be an ISR.
The ISR name is chosen from the device linker script.
*/
void __attribute__((__interrupt__)) _INT0Interrupt(void)
{
           short int a = PORTDbits.RD0;
           short int b = PORTDbits.RD1;
           short int c = PORTDbits.RD2;
           short int d = PORTDbits.RD3;

           //this finds the decimal number of the key pushed
           int num = (a*8)+(b*4)+(c*2)+d;
```

```
          //this determines if the most recent key press matches
the previous one
          if(num == lastPressed)
          {
                repeat = repeat + 1;
                if(keys[repeat][num] == '\0')
                {
                      repeat = 0;
                }
                else
                {
                      goBack();
                }
          }
          else
          {
                repeat = 0;
          }

          //this is for backspace, it goes back and erases the
character in the process
          if(num == 3 && inputCount != 0)
          {
                goBack();
                printCharacter(' ');
                goBack();
                input[inputCount - 1] = '\0';
                inputCount = inputCount - 1;
          }
          //this checks to see if the enter button was pressed,
this functionality will be different
          //in the final design but for now it just clears the
screen and prints the entered character
          //back out to the screen to make sure that it was
saved correctly
          else if(num == 7)
          {
                int i;
                clearLCD();
                printString(input, inputCount);
                for(i=0; i < inputCount; i++)
                {
                      input[i] = '\0';
                }
                inputCount = 0;
          }
          //this is if any of the other keys were pressed, it
just prints out the appropriate character
          else
          {
                printCharacter(keys[repeat][num]);
                char temp[2];
                temp[0] = keys[repeat][num];
          temp[1] = '\0';
                strcat(input, temp);
                inputCount = inputCount + 1;
          }

          lastPressed = num;
        IFS0bits.INT0IF = 0;    //Clear the INT0 interrupt flag
or else
                                //the CPU will keep vectoring
back to the ISR
}
```

# Appendix E

## RFID Reader

# RFID Card Reader, Serial (#28140)
# RFID Card Reader, USB (#28340)




## Introduction

Designed in cooperation with Grand Idea Studio (www.grandideastudio.com), the Parallax Radio Frequency Identification (RFID) Card Readers provide a low-cost solution to read passive RFID transponder tags up to 4 inches away. The RFID Card Readers can be used in a wide variety of hobbyist and commercial applications, including access control, user identification, robotics navigation, inventory tracking, payment systems, car immobilization, and manufacturing automation. The RFID Card Reader is available in two versions: A TTL-level serial interface for use with a microcontroller and a USB interface for direct connection to a computer.

## Features

- Low-cost method for reading passive, 125 kHz RFID transponder tags
- Two easy-to-use versions: Serial interface for microcontrollers and USB for direct connection to PC, Macintosh, or Linux machines
- Bi-color LED for visual indication of status

## RFID Compatibility

The Parallax RFID Card Reader works exclusively with the EM Microelectronics EM4100-family of passive read-only transponder tags. Each transponder tag contains a unique, read-only identifier (one of $2^{40}$, or 1,099,511,627,776 possible combinations).

A variety of different tag types and styles exist with the most popular made available from Parallax.

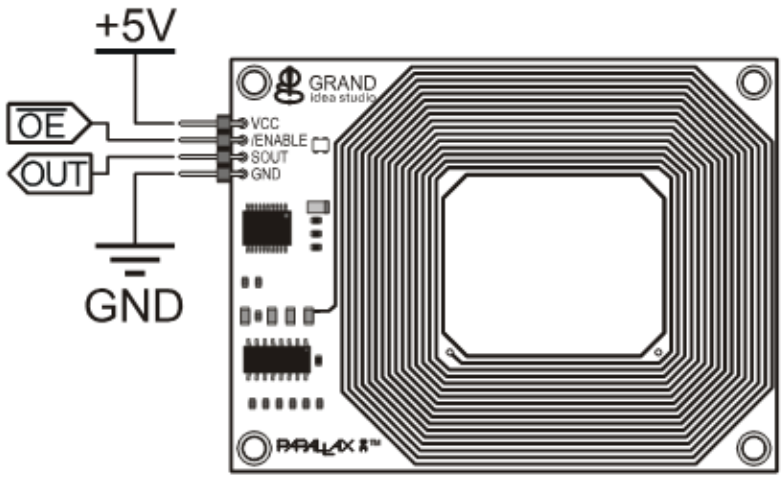
## Connections (Serial)

The Parallax RFID Card Reader Serial version easily interfaces to any host microcontroller using only four connections (VCC, /ENABLE, SOUT, GND).

| Pin | Pin Name | Type | Function |
|---|---|---|---|
| 1 | VCC | P | System power. +5V DC input. |
| 2 | /ENABLE | I | Module enable pin. Active LOW digital input. Bring this pin LOW to enable the RFID reader and activate the antenna. |
| 3 | SOUT | O | Serial output to host. TTL-level interface, 2400 bps, 8 data bits, no parity, 1 stop bit. |
| 4 | GND | G | System ground. Connect to power supply's ground (GND) terminal. |

Note: Type: I = Input, O = Output, P = Power, G = Ground

Use the following example circuit for connecting the Parallax RFID Card Reader:



## Usage

A visual indication of the state of the RFID Card Reader is given with the on-board LED. When the module is successfully powered-up and is in an idle state, the LED will be GREEN. When the module is in an active state searching for or communicating with a valid tag, the LED will be RED.

The RFID Card Reader Serial version is activated via the /ENABLE pin on the module's 4-pin header. When the RFID Card Reader is powered and /ENABLE is pulled LOW, the module will enter the active state. When /ENABLE is pulled HIGH or left unconnected, the module will enter the idle state.

The RFID Card Reader USB version is activated via the DTR line of the USB Virtual COM port. When the DTR line is set HIGH, the module will enter the active state. When the DTR line is set LOW, the module will enter the idle state.

The face of the RFID tag should be held parallel to the front or back face of the antenna (where the majority of RF energy is emitted). If the tag is held sideways (for example, perpendicular to the antenna), you'll either get no reading or a poor reading distance. Only one transponder tag should be held up to the antenna at any time. The use of multiple tags at one time will cause tag collisions and the reader may not detect any of them. The tags available in the Parallax store have a read distance of approximately 4 inches. Actual distance may vary slightly depending on the size of the transponder tag and environmental conditions of the application.

## Communication Protocol

All communication is 8 data bits, no parity, 1 stop bit, and least significant bit first (8N1) at 2400 bps.

The RFID Card Reader Serial version transmits data as 5V TTL-level, non-inverted asynchronous serial.

The RFID Card Reader USB version transmits the data through the USB Virtual COM Port driver. This allows easy access to the serial data stream from any software application, programming language, or interface that can communicate with a COM port.

When the RFID Card Reader is active and a valid RFID transponder tag is placed within range of the activated reader, the tag's unique ID will be transmitted as a 12-byte printable ASCII string serially to the host in the following format:

| Start Byte (0x0A) | Unique ID Digit 1 | Unique ID Digit 2 | Unique ID Digit 3 | Unique ID Digit 4 | Unique ID Digit 5 | Unique ID Digit 6 | Unique ID Digit 7 | Unique ID Digit 8 | Unique ID Digit 9 | Unique ID Digit 10 | Stop Byte (0x0D) |
|---|---|---|---|---|---|---|---|---|---|---|---|

The start byte and stop byte are used to easily identify that a correct string has been received from the reader (they correspond to line feed and carriage return characters, respectively). The middle ten bytes are the actual tag's unique ID. For example, for a tag with a valid ID of 0F0184F07A, the following bytes would be sent: 0x0A, 0x30, 0x46, 0x30, 0x31, 0x38, 0x34, 0x46, 0x30, 0x37, 0x41, 0x0D.

## Interference

The Parallax RFID Card Reader, like many RF devices, may experience RF noise in its frequency range. This may cause the reader to transmit a spurious tag response when no tag is near the unit. This will not affect most uses of the RFID Card Reader. To avoid treating spurious responses as legitimate tags, it is recommended to read two responses in a row within a given amount of time (for example, one second) to ensure that you are reading a valid tag and not a "tag" generated by noise.

## DC Characteristics

At $V_{CC}$ = +5.0V and $T_A$ = 25ºC unless otherwise noted

| Parameter | Symbol | Test Conditions | Specification | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min. | Typ. | Max. | |
| Supply Voltage | $V_{CC}$ | --- | 4.5 | 5.0 | 5.5 | V |
| Supply Current, Idle | $I_{IDLE}$ | --- | --- | 10 | --- | mA |
| Supply Current, Active | $I_{CC}$ | --- | --- | 100 | 200 | mA |
| Input LOW voltage | $V_{IL}$ | +4.5V <= $V_{CC}$ <= +5.5V | --- | --- | 0.8 | V |
| Input HIGH voltage | $V_{IH}$ | +4.5V <= $V_{CC}$ <= +5.5V | 2.0 | --- | --- | V |
| Output LOW voltage | $V_{OL}$ | $V_{CC}$ = +4.5V | --- | --- | 0.6 | V |
| Output HIGH voltage | $V_{OH}$ | $V_{CC}$ = +4.5V | $V_{CC}$ - 0.7 | --- | --- | V |

### *Absolute Maximum Ratings*

| Condition | Value |
|---|---|
| Operating Temperature | -40°C to +85°C |
| Storage Temperature | -55°C to +125°C |
| Supply Voltage ($V_{cc}$) | +4.5V to +5.5V |
| Ground Voltage ($V_{ss}$) | 0V |
| Voltage on any pin with respect to $V_{ss}$ | -0.3V to +7.0V |

**NOTICE:** Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

## RFID Technology Overview

*Material in this section is based on information provided by the RFID Journal (www.rfidjournal.com).*

Radio Frequency Identification (RFID) is a generic term for non-contacting technologies that use radio waves to automatically identify people or objects. There are several methods of identification, but the most common is to store a unique serial number that identifies a person or object on a microchip that is attached to an antenna. The combined antenna and microchip are called an "RFID transponder" or "RFID tag" and work in combination with an "RFID reader" (sometimes called an "RFID interrogator").

An RFID system consists of a reader and one or more tags. The reader's antenna is used to transmit radio frequency (RF) energy. Depending on the tag type, the energy is "harvested" by the tag's antenna and used to power up the internal circuitry of the tag. The tag will then modulate the electromagnetic waves generated by the reader in order to transmit its data back to the reader. The reader receives the modulated waves and converts them into digital data.

There are two major types of tag technologies. "Passive tags" are tags that do not contain their own power source or transmitter. When radio waves from the reader reach the chip's antenna, the energy is converted by the antenna into electricity that can power up the microchip in the tag (typically via inductive coupling). The tag is then able to send back any information stored on the tag by modulating the reader's electromagnetic waves. "Active tags" have their own power source and transmitter. The power source, usually a battery, is used to run the microchip's circuitry and to broadcast a signal to a reader. Due to the fact that passive tags do not have their own transmitter and must reflect their signal

to the reader, the reading distance is much shorter than with active tags. However, active tags are typically larger, more expensive, and require occasional service.

Frequency refers to the size of the radio waves used to communicate between the RFID system components. Just as you tune your radio to different frequencies in order to hear different radio stations, RFID tags and readers must be tuned to the same frequency in order to communicate effectively. RFID systems typically use one of the following frequency ranges: low frequency (or LF, around 125 kHz), high frequency (or HF, around 13.56 MHz), ultra-high frequency (or UHF, around 868 and 928 MHz), or microwave (around 2.45 and 5.8 GHz).

The read range of a tag ultimately depends on many factors: the frequency of RFID system operation, the power of the reader, and interference from other RF devices. Balancing a number of engineering trade-offs (antenna size v. reading distance v. power v. manufacturing cost), the Parallax RFID Card Reader's antenna was designed specifically for use with low-frequency (125 kHz) passive tags with a read distance of around 4 inches.

```
/*    Ethan Lilly
      This program will allow for an RFID card to be read and a
confirmation message to be
      displayed on and LCD screen
*/

#include <p30f6015.h>
#include "lcd.h"

/* Macros for Configuration Fuse Registers (copied from device
header file):*/
_FOSC(CSW_FSCM_OFF & FRC & XT_PLL8);  /* Set up for Crystal
multiplied by 8x PLL */
_FWDT(WDT_OFF);                 /* Turn off the Watch-Dog Timer.
*/

//functions
void initRFID()
{
      //set the enable pin on the RFID reader to LOW
      PORTFbits.RF5 = 0;
      //printString("The RFID reader has been enabled", 32);
}

void initUART()
{
      U2BRG = 0x00C7;       //set the baud rate to 2400 bps
      U2MODEbits.PDSEL0 = 0;
      U2MODEbits.PDSEL1 = 0;      //set UART to 8 bit no parity
      U2MODEbits.STSEL = 0;   //set UART to 1 stop bit
      U2STA = 0;       //the interrupt is triggered as soon as a
character is recieved
      IFS1bits.U2RXIF = 0;  //set the interrupt flag to low
      IEC1bits.U2RXIE = 1;  //enable the interrupt
      U2MODEbits.UARTEN = 1; //enable the UART Module
}
```

```
void __attribute__((__interrupt__)) _U2RXInterrupt(void);

int main()
{
      PORTE = 0;                    //Set all of PORTE to 0
     TRISE = 0x0000;              //make these ports set to output
      PORTB = 0;                    //Set all of PORTE to 0
     TRISB = 0x0000;              //make these ports set to output
      PORTFbits.RF5 = 1;           //set the enable pin on the
RFID reader to HIGH
      TRISF = 0x0000;              //st all of PORTF to output

      initLCD();
      initUART();
      initRFID();


      while(1)
      {
            //wait for input
      }

      return 0;
}

//this interrupt is triggered once it begins to recieve data from
the RFID reader
//It currently doesn't do anything with the data to make sure
that the data received
//matches the ID of a card, but this will hopefully be fixed in
the near future
void __attribute__((__interrupt__)) _U2RXInterrupt(void)
{
      printString("A card was detected", 19);

      IEC1bits.U2RXIE = 0;  //disable the interrupt
      U2MODEbits.UARTEN = 0; //disable the UART Module
      PORTFbits.RF5 = 1;           //set the enable pin on the
RFID reader to HIGH

       IFS1bits.U2RXIF = 0;  //set the interrupt flag to low
 }
```

# Appendix F

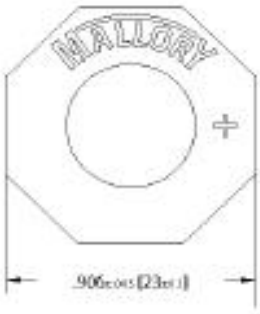
## Alarm

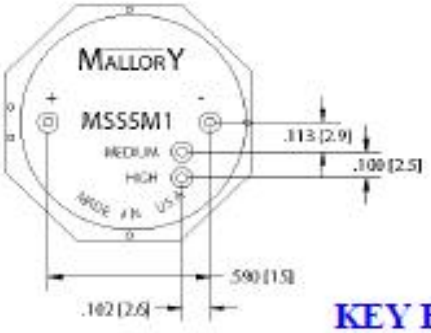
MALLORY SONALERT PRODUCTS, INC.

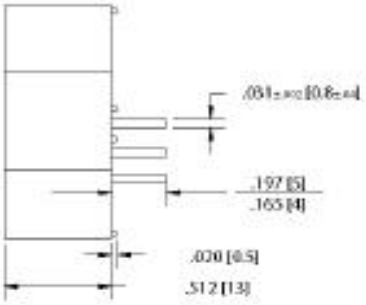
# Product APPLICATION Guide

## Part Number: MSS5M1

### For IEC60601-1-8 Medical Applications




**KEY FEATURES:**

- Designed to Meet IEC 60601-1-8
- 975 Hz Fundamental Frequency
- 4 Harmonic Peaks within ±15 dB (1 to 4 kHz)
- 88 dB @ 10 cm Typical
- Three priority sounds (low, medium, & high)

## Specifications:

| | |
|---|---|
| **Voltage Range:** | 5.0 ± 0.5 Vdc |
| **Sound Level:** | 88 dB @ 10 cm Typical |
| **Frequency:** | 975 ± 24 Hz |
| **Sound Harmonics:** | Minimum of 4 (1 to 4 kHz) |
| **Operating Temp:** | -30°C to +70 °C |
| **Storage Temp:** | -30 °C to +70 °C |
| **Case Material:** | Valox (UL94-V0) |
| **Current Level:** | < 250 mA during BEEP time<br>< 10 mA during PAUSE time |

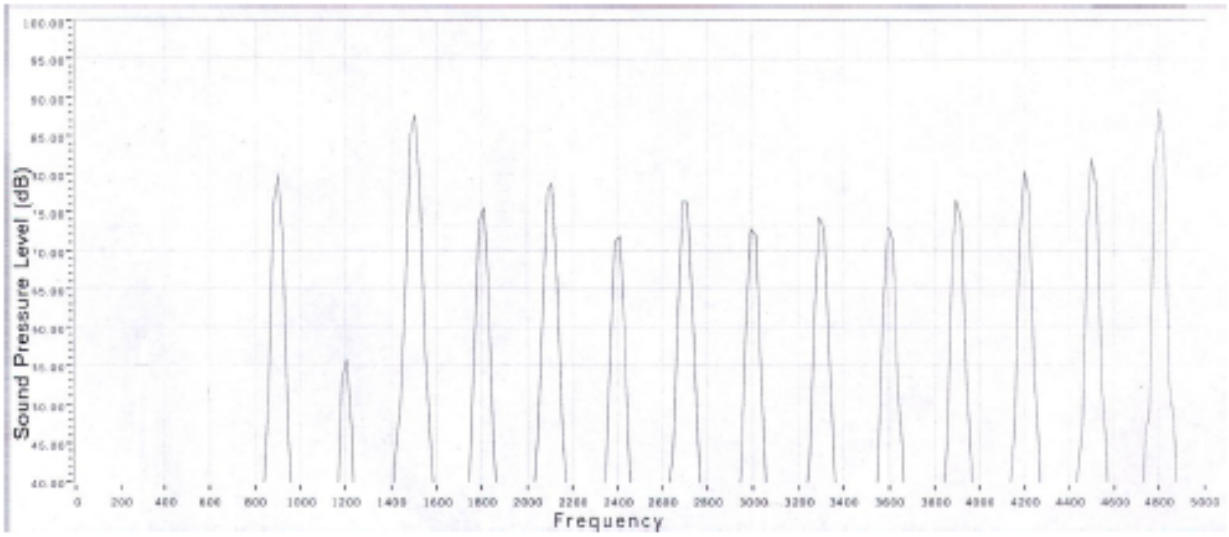
| | |
|---|---|
| ***Low Priority Signal** | 2 Beeps that Repeat |
| ***Med Priority Signal** | 3 Beeps that Repeat |
| ***High Priority Signal** | 10 Beeps that Repeat |

*per IEC 60601-1-8 Tables 203 & 204

**Continued** ⟶

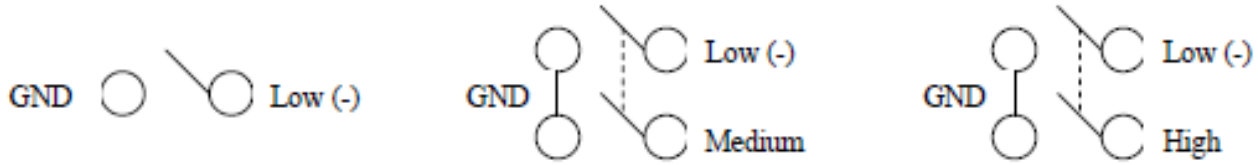
# MSS5M1 Alarm (Con't)

## Frequency Response:




As shown above, the fundamental frequency is 975 Hz, and there are more than 4 harmonic peaks between 1 and 4 kHz. All harmonic peaks are within ± 15 dB of the fundamental frequency

## Priority Signal Activation:




**Low Priority** **Medium Priority** **High Priority**

## Priority Signal Details:

- Low Priority: *Beep*, Pause 200ms, *Beep*; Repeat every 20 sec's
- Med Priority: *Beep*, Pause 200ms, *Beep*, Pause 200ms, *Beep*; Repeat every 7.5 sec's
- High Priority: *Beep*, Pause 100ms, *Beep*, Pause 100ms, *Beep*, Pause 300ms, *Beep*, Pause 100ms, *Beep*, Pause 500ms, *Beep*, Pause 100ms, *Beep*, Pause 100ms, *Beep*, Pause 300ms, *Beep*, Pause 100ms, *Beep*; Repeat every 2.5 sec's

Note: Beep "on" time is 100ms (high priority) & 200ms (low & medium priority).

Call 317-612-1000 or Visit www.mallory-sonalert.com for More Details

# Appendix G

## Force Sensors

INTERLINK ELECTRONICS
Sensor Technologies

# FSR 402 Data Sheet

## FSR 400 Series Round Force Sensing Resistor

## Description

Interlink Electronics FSR™ 400 series is part of the single zone Force Sensing Resistor™ family. Force Sensing Resistors, or FSRs, are robust polymer thick film (PTF) devices that exhibit a decrease in resistance with increase in force applied to the surface of the sensor. This force sensitivity is optimized for use in human touch control of electronic devices such as automotive electronics, medical systems, and in industrial and robotics applications.

The standard 402 sensor is a round sensor 18.28 mm in diameter. Custom sensors can be manufactured in sizes ranging from 5mm to over 600mm. Female connector and short tail versions can also be ordered.

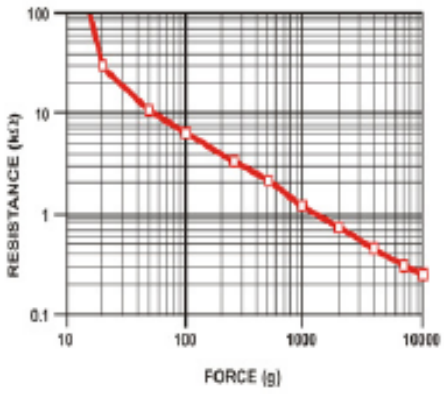
## Features and Benefits

- Actuation Force as low as 0.1N and sensitivity range to 10N.
- Easily customizable to a wide range of sizes
- Highly Repeatable Force Reading; As low as 2% of initial reading with repeatable actuation system
- Cost effective
- Ultra thin; 0.45mm
- Robust; up to 10M actuations
- Simple and easy to integrate

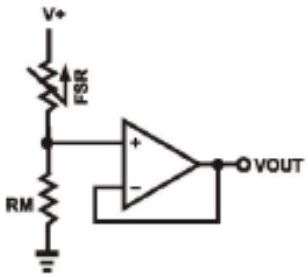
## Industry Segments

- Game controllers
- Musical instruments
- Medical device controls
- Remote controls
- Navigation Electronics
- Industrial HMI
- Automotive Panels
- Consumer Electronics

### Figure 1 - Force Curve




### Figure 2 - Schematic




Interlink Electronics - Sensor Technologies

INTERLINK ELECTRONICS
Sensor Technologies

# FSR 402
P/N: 30-81794

## Applications

**Detect & qualify press**
Sense whether a touch is accidental or intended by reading force

**Use force for UI feedback**
Detect more or less user force to make a more intuitive interface

**Enhance tool safety**
Differentiate a grip from a touch as a safety lock

**Find centroid of force**
Use multiple sensors to determine centroid of force

**Detect presence, position, or motion**
Of a person or patient in a bed, chair, or medical device

**Detect liquid blockage**
Detect tube or pump occlusion or blockage by measuring back pressure

**Detect proper tube positioning**

**Many other force measurement applications**

## Device Characteristics

| Feature | Condition | Value* | Notes |
|---|---|---|---|
| **Actuation Force** | | 0.1 Newtons | |
| **Force Sensitivity Range** | | 0.1 - 10.0[2] Newtons | |
| **Force Repeatability**[3] | (Single part) | ± 2% | |
| **Force Resolution**[3] | | continuous | |
| **Force Repeatability**[3] | (Part to Part) | ±6% | |
| **Non-Actuated Resistance** | | 10M W | |
| **Size** | | 18.28mm diameter | |
| **Thickness Range** | | 0.2 - 1.25 mm | |
| **Stand-Off Resistance** | | >10M ohms | Unloaded, unbent |
| **Switch Travel** | (Typical) | 0.05 mm | Depends on design |
| **Hysteresis**[3] | | +10% | $(R_{F+} - R_{F-})/R_{F+}$ |
| **Device Rise Time** | | <3 microseconds | measured w/steel ball |
| **Long Term Drift** | | <5% per $\log_{10}$(time) | 35 days test, 1kg load |
| **Temp Operating Range** | (Recommended) | -30 - +70 °C | |
| **Number of Actuations** | (Life time) | 10 Million tested | Without failure |

* Specifications are derived from measurements taken at 1000 grams, and are given as one standard deviation / mean, unless otherwise noted.

1. Max Actuation force can be modified in custom sensors.
2. Force Range can be increased in custom sensors. Interlink Electronics have designed and manufactured sensors with operating force larger than 50Kg.
3. Force sensitivity dependent on mechanics, and resolution depends on measurement electronics.

## Application Information

FSRs are two-wire devices with a resistance that depends on applied force.

For specific application needs please contact Interlink Electronics support team. An integration guide is also available.

For a simple force-to-voltage conversion, the FSR device is tied to a measuring resistor in a voltage divider configuration (see Figure 3). The output is described by the equation:

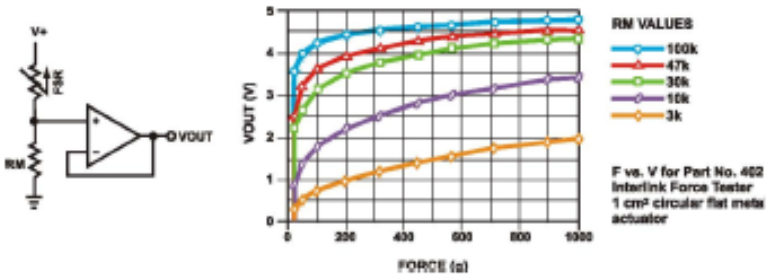
$$V_{OUT} = \frac{R_M V +}{(R_M + R_{FSR})}$$

In the shown configuration, the output voltage increases with increasing force. If $R_{FSR}$ and $R_M$ are swapped, the output swing will decrease with increasing force.

The measuring resistor, $R_M$, is chosen to maximize the desired force sensitivity range and to limit current. Depending on the impedance requirements of the measuring circuit, the voltage divider could be followed by an op-amp.

A family of force vs. $V_{OUT}$ curves is shown on the graph below for a standard FSR in a voltage divider configuration with various $R_M$ resistors. A (V+) of +5V was used for these examples.

### Figure 3

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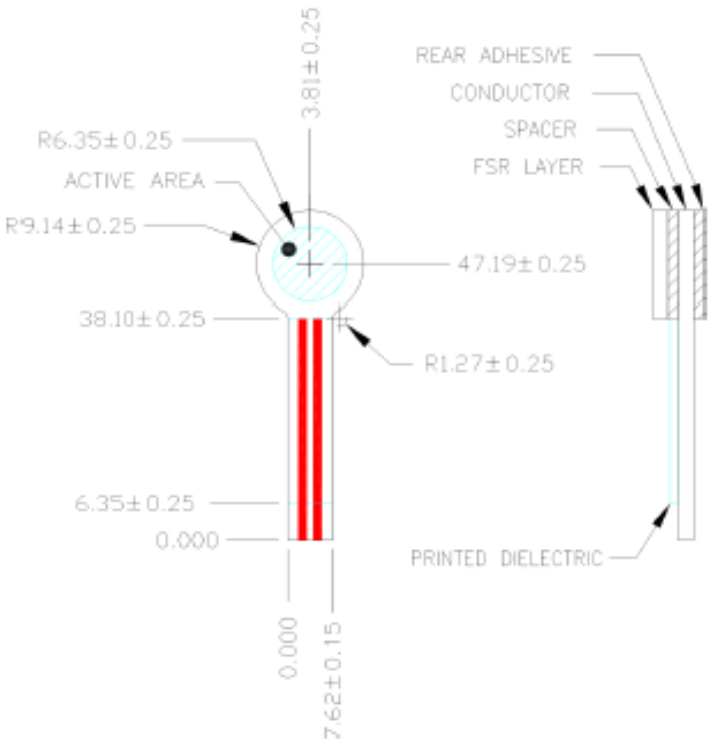
Korea Sales Office
Phone: +82 10 8776 1972

INTERLINK ELECTRONICS
Sensor Technologies

# FSR 402
P/N: 30-81794

## Mechanical Data




## Part No. 402

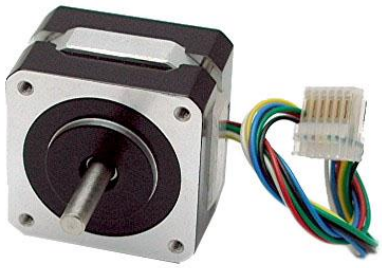
- Active Area: 12.7mm
- Nominal thickness: 0.55 mm

P/N: 94-00011 Rev. A

Interlink Electronics - Sensor Technologies

# Appendix H

## Motor



## Motor No.: 417-11-48-02

| | |
|---|---|
| **FULL STEP ANGLE** | 0.9° |
| **MOTOR FRAME SIZE** | NEMA Size 17 |
| **BODY LENGTH** | 1.1" Maximum |
| **RATED CURRENT/PHASE** | 0.3Amps |
| **RESISTANCE/PHASE** | 48.1Ω ±10% |
| **INDUCTANCE/PH** | 16.46mH±20% |
| **ROTOR INERTIA** | 0.07oz-in^2 |
| **BEARING TYPE** | ABEC3 |
| **NOMINAL HOLDING TORQUE 2 PHASE ON (±10%)** | 10.78 oz-in |
| **AMBIENT OPERATING TEMPERATURE** | -20° C to 50° C |
| **AMBIENT OPERATING HUMIDITY(non condensing)** | 85% Max |
| **LEAD WIRES** | (6) # 24 AWG PVC |
| **DIELECTRIC STRENGTH** | 500V |

**LEAD WIRE CONNECTION**

| | |
|---|---|
| **A** | **RED** |
| **A/C** | **WHITE** |
| **C** | **BLUE** |
| **B** | **GREEN** |
| **B/D** | **YELLOW** |
| **D** | **BLACK** |

# Appendix I

## Real Time Clock

# DS1307
# 64 x 8, Serial, I²C Real-Time Clock

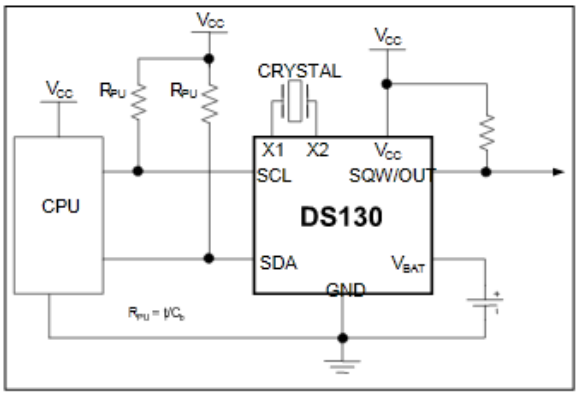
## GENERAL DESCRIPTION

The DS1307 serial real-time clock (RTC) is a low-power, full binary-coded decimal (BCD) clock/calendar plus 56 bytes of NV SRAM. Address and data are transferred serially through an I²C, bidirectional bus. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The end of the month date is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with AM/PM indicator. The DS1307 has a built-in power-sense circuit that detects power failures and automatically switches to the backup supply. Timekeeping operation continues while the part operates from the backup supply.

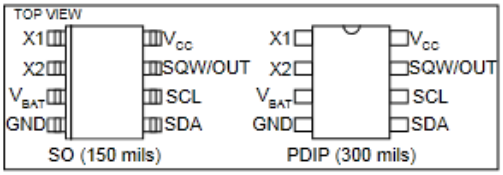
## FEATURES

- Real-Time Clock (RTC) Counts Seconds, Minutes, Hours, Date of the Month, Month, Day of the week, and Year with Leap-Year Compensation Valid Up to 2100
- 56-Byte, Battery-Backed, General-Purpose RAM with Unlimited Writes
- I²C Serial Interface
- Programmable Square-Wave Output Signal
- Automatic Power-Fail Detect and Switch Circuitry
- Consumes Less than 500nA in Battery-Backup Mode with Oscillator Running
- Optional Industrial Temperature Range: -40°C to +85°C
- Available in 8-Pin Plastic DIP or SO
- Underwriters Laboratories (UL) Recognized

## TYPICAL OPERATING CIRCUIT




## PIN CONFIGURATIONS




## ORDERING INFORMATION

| PART | TEMP RANGE | VOLTAGE (V) | PIN-PACKAGE | TOP MARK* |
|---|---|---|---|---|
| DS1307+ | 0°C to +70°C | 5.0 | 8 PDIP (300 mils) | DS1307 |
| DS1307N+ | -40°C to +85°C | 5.0 | 8 PDIP (300 mils) | DS1307N |
| DS1307Z+ | 0°C to +70°C | 5.0 | 8 SO (150 mils) | DS1307 |
| DS1307ZN+ | -40°C to +85°C | 5.0 | 8 SO (150 mils) | DS1307N |
| DS1307Z+T&R | 0°C to +70°C | 5.0 | 8 SO (150 mils) Tape and Reel | DS1307 |
| DS1307ZN+T&R | -40°C to +85°C | 5.0 | 8 SO (150 mils) Tape and Reel | DS1307N |

*+Denotes a lead-free/RoHS-compliant package.*
**A "+" anywhere on the top mark indicates a lead-free package. An "N" anywhere on the top mark indicates an industrial temperature range device.*

## ABSOLUTE MAXIMUM RATINGS

Voltage Range on Any Pin Relative to Ground ..... -0.5V to +7.0V
Operating Temperature Range (Noncondensing)
Commercial ..... 0°C to +70°C
Industrial ..... -40°C to +85°C
Storage Temperature Range ..... -55°C to +125°C
Soldering Temperature (DIP, leads) ..... +260°C for 10 seconds
Soldering Temperature (surface mount) ..... Refer to the JPC/JEDEC J-STD-020 Specification.

*Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to the absolute maximum rating conditions for extended periods may affect device reliability.*

## RECOMMENDED DC OPERATING CONDITIONS

**($T_A$ = 0°C to +70°C, $T_A$ = -40°C to +85°C.) (Notes 1, 2)**

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Supply Voltage | $V_{CC}$ | | 4.5 | 5.0 | 5.5 | V |
| Logic 1 Input | $V_{IH}$ | | 2.2 | | $V_{CC}$ + 0.3 | V |
| Logic 0 Input | $V_{IL}$ | | -0.3 | | +0.8 | V |
| $V_{BAT}$ Battery Voltage | $V_{BAT}$ | | 2.0 | 3 | 3.5 | V |

## DC ELECTRICAL CHARACTERISTICS

**($V_{CC}$ = 4.5V to 5.5V; $T_A$ = 0°C to +70°C, $T_A$ = -40°C to +85°C.) (Notes 1, 2)**

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Input Leakage (SCL) | $I_{LI}$ | | -1 | | 1 | µA |
| I/O Leakage (SDA, SQW/OUT) | $I_{LO}$ | | -1 | | 1 | µA |
| Logic 0 Output ($I_{OL}$ = 5mA) | $V_{OL}$ | | | | 0.4 | V |
| Active Supply Current ($f_{SCL}$ = 100kHz) | $I_{CCA}$ | | | | 1.5 | mA |
| Standby Current | $I_{CCS}$ | (Note 3) | | | 200 | µA |
| $V_{BAT}$ Leakage Current | $I_{BATLKG}$ | | | 5 | 50 | nA |
| Power-Fail Voltage ($V_{BAT}$ = 3.0V) | $V_{PF}$ | | 1.216 x $V_{BAT}$ | 1.25 x $V_{BAT}$ | 1.284 x $V_{BAT}$ | V |

## DC ELECTRICAL CHARACTERISTICS

**($V_{CC}$ = 0V, $V_{BAT}$ = 3.0V; $T_A$ = 0°C to +70°C, $T_A$ = -40°C to +85°C.) (Notes 1, 2)**

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| $V_{BAT}$ Current (OSC ON); SQW/OUT OFF | $I_{BAT1}$ | | | 300 | 500 | nA |
| $V_{BAT}$ Current (OSC ON); SQW/OUT ON (32kHz) | $I_{BAT2}$ | | | 480 | 800 | nA |
| $V_{BAT}$ Data-Retention Current (Oscillator Off) | $I_{BATDR}$ | | | 10 | 100 | nA |

**WARNING: Negative undershoots below -0.3V while the part is in battery-backed mode may cause loss of data.**

## TIMING DIAGRAM

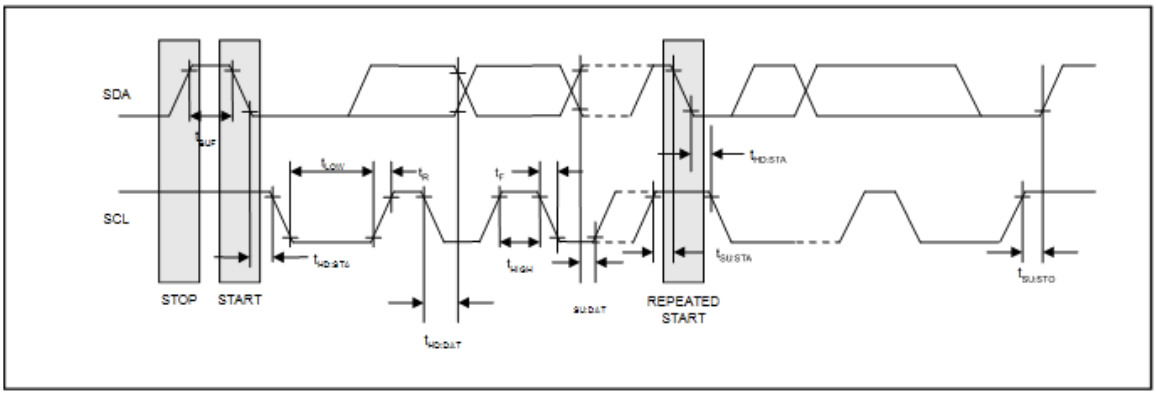
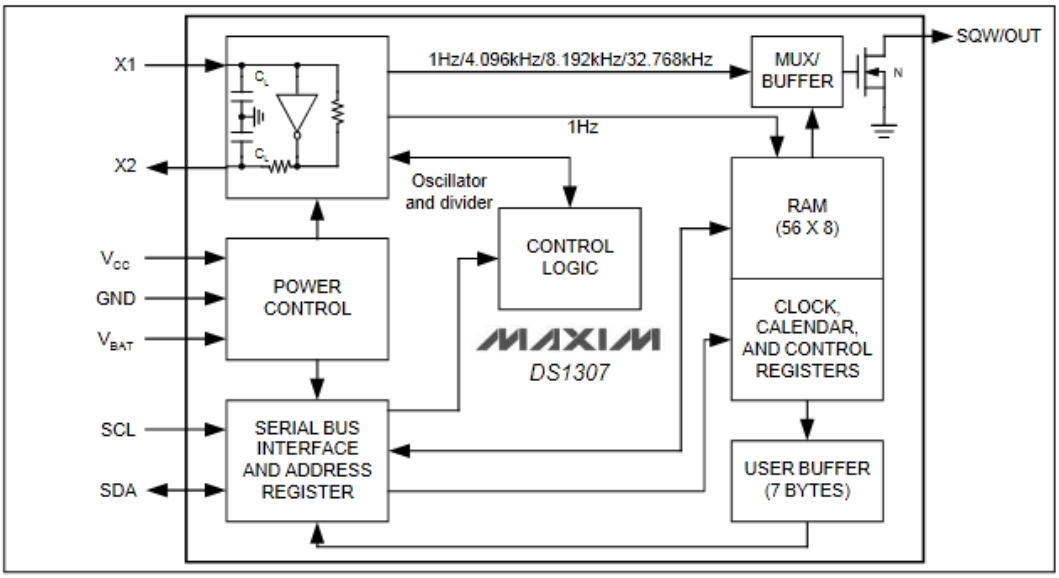



**Figure 1. Block Diagram**



## PIN DESCRIPTION

| PIN | NAME | FUNCTION |
|---|---|---|
| 1 | X1 | Connections for Standard 32.768kHz Quartz Crystal. The internal oscillator circuitry is designed for operation with a crystal having a specified load capacitance ($C_L$) of 12.5pF. X1 is the input to the oscillator and can optionally be connected to an external 32.768kHz oscillator. The output of the internal oscillator, X2, is floated if an external oscillator is connected to X1.<br>**Note:** For more information on crystal selection and crystal layout considerations, refer to *Application Note 58: Crystal Considerations with Dallas Real-Time Clocks*. |
| 2 | X2 | |
| 3 | $V_{BAT}$ | Backup Supply Input for Any Standard 3V Lithium Cell or Other Energy Source. Battery voltage must be held between the minimum and maximum limits for proper operation. Diodes in series between the battery and the $V_{BAT}$ pin may prevent proper operation. If a backup supply is not required, $V_{BAT}$ must be grounded. The nominal power-fail trip point ($V_{PF}$) voltage at which access to the RTC and user RAM is denied is set by the internal circuitry as 1.25 x $V_{BAT}$ nominal. A lithium battery with 48mAh or greater will back up the DS1307 for more than 10 years in the absence of power at +25°C.<br>UL recognized to ensure against reverse charging current when used with a lithium battery. Go to: www.maxim-ic.com/qa/info/ul/. |
| 4 | GND | Ground |
| 5 | SDA | Serial Data Input/Output. SDA is the data input/output for the I²C serial interface. The SDA pin is open drain and requires an external pullup resistor. The pullup voltage can be up to 5.5V regardless of the voltage on $V_{CC}$. |
| 6 | SCL | Serial Clock Input. SCL is the clock input for the I²C interface and is used to synchronize data movement on the serial interface. The pullup voltage can be up to 5.5V regardless of the voltage on $V_{CC}$. |
| 7 | SQW/OUT | Square Wave/Output Driver. When enabled, the SQWE bit set to 1, the SQW/OUT pin outputs one of four square-wave frequencies (1Hz, 4kHz, 8kHz, 32kHz). The SQW/OUT pin is open drain and requires an external pullup resistor. SQW/OUT operates with either $V_{CC}$ or $V_{BAT}$ applied. The pullup voltage can be up to 5.5V regardless of the voltage on $V_{CC}$. If not used, this pin can be left floating. |
| 8 | $V_{CC}$ | Primary Power Supply. When voltage is applied within normal limits, the device is fully accessible and data can be written and read. When a backup supply is connected to the device and $V_{CC}$ is below $V_{TP}$, read and writes are inhibited. However, the timekeeping function continues unaffected by the lower input voltage. |

## DETAILED DESCRIPTION

The DS1307 is a low-power clock/calendar with 56 bytes of battery-backed SRAM. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The date at the end of the month is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The DS1307 operates as a slave device on the I²C bus. Access is obtained by implementing a START condition and providing a device identification code followed by a register address. Subsequent registers can be accessed sequentially until a STOP condition is executed. When $V_{CC}$ falls below 1.25 x $V_{BAT}$, the device terminates an access in progress and resets the device address counter. Inputs to the device will not be recognized at this time to prevent erroneous data from being written to the device from an out-of-tolerance system. When $V_{CC}$ falls below $V_{BAT}$, the device switches into a low-current battery-backup mode. Upon power-up, the device switches from battery to $V_{CC}$ when $V_{CC}$ is greater than $V_{BAT}$ +0.2V and recognizes inputs when $V_{CC}$ is greater than 1.25 x $V_{BAT}$. The block diagram in Figure 1 shows the main elements of the serial RTC.

# Appendix J

## Power Supply

# BLP55 AC-DC Series Data Sheet
## 55 Watts

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RoHS Compliant

### Features

- RoHS lead-free solder and lead-solder-exempted products are available
- Industry-standard 3" x 5" footprint
- Main output remote sense
- CE marked to Low Voltage Directive
- Compliance to EN61000-4-2/-3/-4/-5/-6/-8

### Description

The BLP55 Series' economical and compact construction provides single or three-output ac-dc power conversion to meet the requirements of networking and data communications systems, as well as commercial and industrial configurations.

The BLP55 is rated for convection, as well as forced-air cooling. Full output power is available with external forced-air cooling. Other features include main-output remote sense and an internal EMI filter.

### Single Output Model Selection

| MODEL | NOMINAL OUTPUT VOLTAGE (VDC) | MIN-MAXIMUM OUTPUT CURRENT, CONVECTION | MIN-MAXIMUM OUTPUT CURRENT [1] | PEAK OUTPUT CURRENT [2] | TOTAL REGULATION % [3] | RIPPLE & NOISE %p-p [4] |
|---|---|---|---|---|---|---|
| **BLP55-1005** | 5V | 0 to 8A | 0 to 11A | 12A | ±2 | 1 |
| **BLP55-1012** | 12V | 0 to 3.3A | 0 to 4.5A | 5A | ±2 | 1 |
| **BLP55-1024** | 24V | 0 to 1.6A | 0 to 2.3A | 2.5A | ±2 | 1 |

### Triple Output Model Selection

| MODEL | NOMINAL OUTPUT VOLTAGE (VDC) | MIN-MAXIMUM OUTPUT CURRENT, CONVECTION | MIN-MAXIMUM OUTPUT CURRENT [1] | PEAK OUTPUT CURRENT [2] | TOTAL REGULATION % [3] | RIPPLE & NOISE %p-p [4] |
|---|---|---|---|---|---|---|
| **BLP55-3000** | +5V | 0.4 to 4A | 0.5 to 5A | 7A | ±2 | 1 |
| | +12V | 0.2 to 2A | 0.2 to 2.5A | 4A | ±5 | 1 |
| | -12V | 0.0 to 0.5A | 0.0 to 0.7A | 1 | ±5 | 1 |
| **BLP55-3300** | +3.3V | 0.5 to 4A | 0.5 to 5A | 7A | ±2.5 | 1 |
| | +5V | 0.0 to 2A | 0.0 to 2.5A | 4A | ±2.5 | 1 |
| | +12V | 0.0 to 0.5A | 0.0 to 0.7A | 1A | ±5 | 1 |

**NOTES:** [1] 10 CFM or 150 LFM (average measurement of six equally-distanced points through a 3.5" x 1.6" cross-sectional area) with power supply mounted on 0.25" standoffs. Recommended airflow direction is from the AC side to the DC side.

[2] Peak current duration for less than 30 Sec with a maximum duty cycle of 10%.

[3] At 25 °C ambient including voltage set point tolerance, line, and load regulation.

[4] Maximum peak-to-peak noise expressed as a percentage of output voltage, 20 MHz bandwidth, and bypass capacitors of 10 µF and 0.1 µF.

### Ordering Information:

| OPTIONS | SUFFIXES TO ADD TO PART NUMBER |
|---|---|
| RoHS lead solder exempt | No RoHS character required. |
| RoHS compliant for all 6 substances | Add "G" as the last character of the part number. |

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## Input Specifications

| PARAMETER | CONDITIONS/DESCRIPTION | | MIN | NOM | MAX | UNITS |
|---|---|---|---|---|---|---|
| Input Voltage - AC | Single-phase continuous input range. | | 85 | 100-250 | 264 | VAC |
| Input Voltage - DC | Consult factory. | | | | | |
| Input Frequency | AC input. | | 47 | 50/60 | 63 | Hz |
| Input Current | At 115 VAC input. | | | 1 | | ARMS |
| Inrush Surge Current | Internally limited. | Vin = 115 VAC, Max Power, 25 °C. | | 18 | | APK |
| | Internally limited. | Vin = 230VAC, Max Power, 25 °C. | | 36 | | APK |
| Input Fuse | Internally located AC input line fuse rated at F, 250 V, 3.15 A. | | | | | |
| Efficiency | At Max Power, -3300 60% nominal. | | | 70 | | % |

## Output Specifications

| PARAMETER | CONDITIONS/DESCRIPTION | | MIN | NOM | MAX | UNITS |
|---|---|---|---|---|---|---|
| Output Power | With convection cooling (-3300 25 W). | See Model Selection Table | | | 40 | Watts |
| | With forced-air cooling (-3300 41 W). | See Model Selection Table | | | 55 | |
| Output DC Adjustability: | Adjustability of Vo1 (Vo2/Vo3 are not adjustable). | | -5%, +10% | | | Of Nom |
| Overshoot | | | | | 5 | % |
| Load Transient | Vo1, Vo2, or Vo3 deviation due to a 50 to 100% load change at a rate of 1A/µs. | | | | ±3 | % |
| Turn-On Time from AC ON | Time required for output voltage to reach within regulation after initial application of AC input. | | | | 1.5 | Sec |
| Turn-On Delay | Time required for output voltage to rise from 10% to 90%. | | | | 20 | ms |
| Hold-Up Time | At 40 W, 115 VAC | | | 20 | | ms |
| Remote Sense | Total compensation for cable losses on Vo1. (Remote Sense is not available for Vo2 or Vo3) | | | | 500 | mV |

## Interface Signals and Internal Protection

| PARAMETER | CONDITIONS/DESCRIPTION | | MIN | NOM | MAX | UNITS |
|---|---|---|---|---|---|---|
| Overvoltage Protection | Main output. | 3.3V: | 3.8 | | 4.5 | V |
| | | 5V: | 5.7 | | 6.8 | |
| | | 12V: | 13.8 | | 16.2 | |
| | | 24V: | 27.6 | | 32.4 | |
| | | 48V: | 52.8 | | 56.4 | |
| Short Circuit Protection | Fully-protected against output short circuit. | | | | | |

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## Safety, Regulatory, and EMI Specifications

| PARAMETER | CONDITIONS/DESCRIPTION | | | MIN | NOM | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Agency Approvals | UL60950-1/CSA 22.2 No. 60950-1-03.<br>EN 60950-1/IEC 60950-1.<br>CB Approval.<br>CE Mark for LVD. | | | | | | |
| Ground Continuity | | | | | | 40 | A |
| Dielectric Withstand Voltage | Input-to-Ground (Basic). | | | 1500<br>2121 | | | VAC<br>VDC |
| | Input-to-Ouput (Reinforced). | The primary to secondary test is not performed on completed assemblies. | | 3000<br>4242 | | | VAC<br>VDC |
| | Output-to-Ground (Functional). | | | 500 | | | VDC |
| Electromagnetic Interference | FCC Part 15.<br>CISPR 22 and CISPR 11. | | Conducted:<br>Conducted: | B<br>B | | | Class |
| ESD | Per EN61000-4-2, level 3. | | | | | | |
| Flicker | Per EN61000-3-3. | | | | | | |
| Radiated Susceptibility | Per EN61000-4-3, level 3. | | | | 3 | | V/m |
| EFT/Burst | Per EN61000-4-4, level 3. | | | 1 | | | kV |
| Input Transient Protection | Per EN61000-4-5, class 3. | | Line-to-Line:<br>Line-to-Ground: | 1<br>2 | | | kV |
| RF Immunity | Per EN61000-4-6, level 3. | | | | 3 | | V/m |
| Magnetic Fields | Per EN61000-4-8. | | | | 1 | | A/m |
| Leakage Current | Per EN60950. | BLP55-1XXX<br>BLP55-3XXX | At 264 VAC:<br>AT 264 VAC: | | | 0.48<br>0.72 | mA |

## Environmental Specifications

| PARAMETER | CONDITIONS/DESCRIPTION | MIN | NOM | MAX | UNITS |
|---|---|---|---|---|---|
| Altitude | Operating.<br>Non-Operating. | | | 10k<br>50k | ASL Ft.<br>ASL Ft. |
| Operating Temperature | 0 °C to 70 °C with linear derating to 50% above 50 °C. Unit will start up at -20 °C but will not meet all published specifications. | 0 | 25 | 70 | °C |
| Storage Temperature | | -40 | | 85 | °C |
| Forced-Air Cooling | Forced-air cooling of 150 LFM at 10 CFM is required for full output power.[1] (See Model Selection Table). | | | | |
| Convection Cooling | When unit is mounted horizontally with free-air convection. (See Model Selection Table). | | | 40 | W |
| Temperature Coefficient | 0 °C to 70 °C (after 15-minute warm-up). | | ±0.02 | | %/°C |
| Relative Humidity | Non-Condensing. | 5 | | 95 | %RH |
| Shock | Operating: half-sine 11 ±3ms, 3 axis.<br>Non-operating: half-sine 11±3ms, 3 axis. | | | 15<br>40 | G |
| Vibration | Operating: Random vibration, 5-500 Hz (10 minutes each axis).<br>Non-operating: Random vibration, 5-500 Hz (10 minutes each axis). | | | 2.4<br>6.0 | Grms<br>Grms |

**NOTES:** [1] 10 CFM or 150 LFM (average measurement of six equally-distanced points through a 3.5" x 1.6" cross-sectional area) with power supply mounted on 0.25" standoffs. Recommended airflow direction is from the AC side to the DC side.

Figure 1. BLP55-3000 Typical Quasi-Regulation Performance for +12V Output

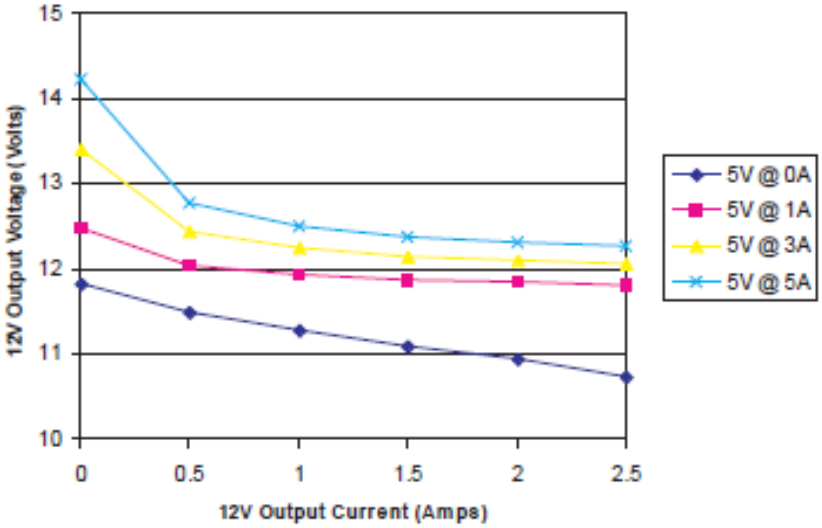
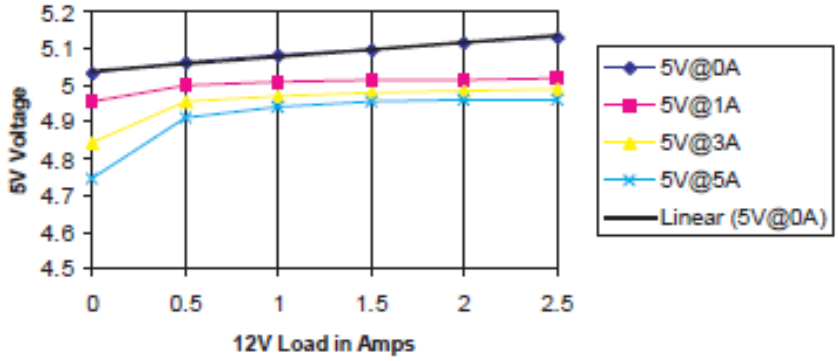
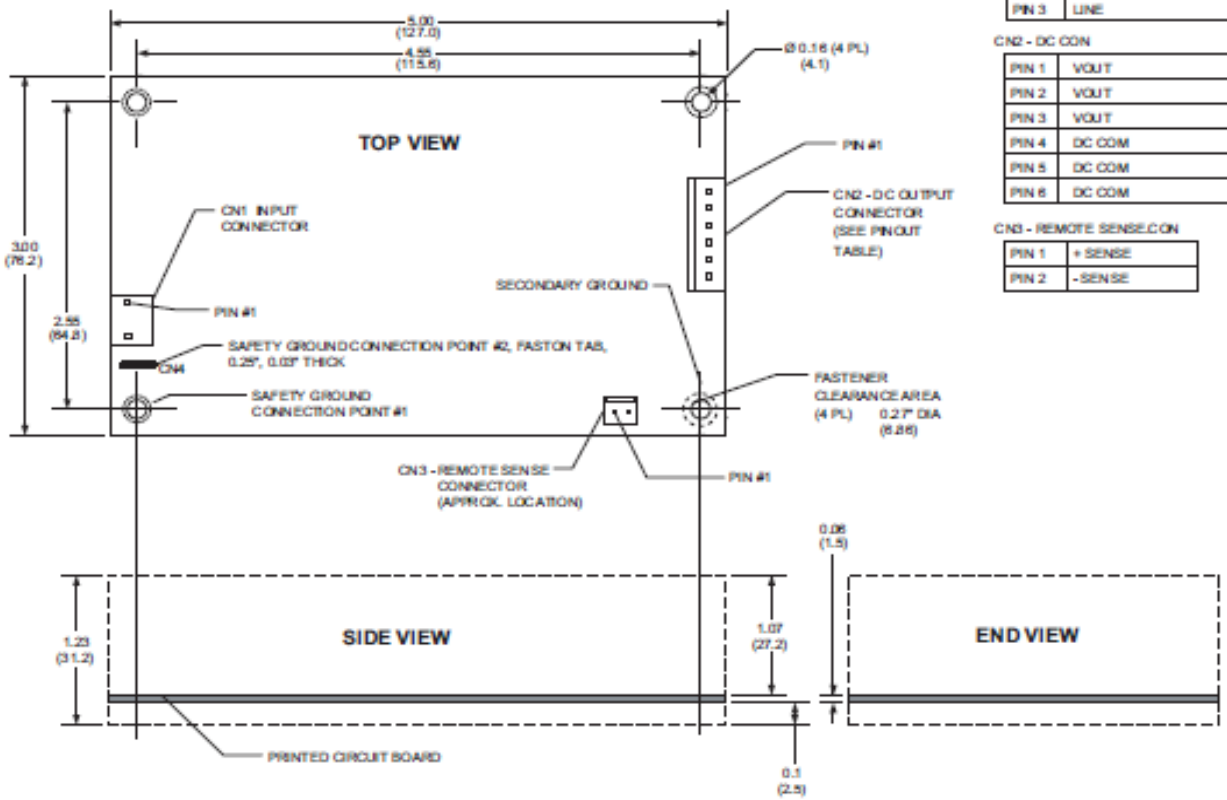



Figure 2. BLP55-3000 5V Output Voltage vs. 12V load



**Overall Size: 3.00" x 5.00" x 1.23" (76.2mm x 127.0mm x 31.2mm) Weight: 0.51 lb (0.23 kg)**

**Mechanical Drawing**
**(Single-Output Models)**




CN1 - AC CONN.

| | |
|---|---|
| PIN 1 | NEUTRAL |
| PIN 2 | MISSING PIN |
| PIN 3 | LINE |

CN2 - DC CON

| | |
|---|---|
| PIN 1 | VOUT |
| PIN 2 | VOUT |
| PIN 3 | VOUT |
| PIN 4 | DC COM |
| PIN 5 | DC COM |
| PIN 6 | DC COM |

CN3 - REMOTE SENSE CON

| | |
|---|---|
| PIN 1 | + SENSE |
| PIN 2 | - SENSE |

RECOMMENDED MATING CONNECTORS

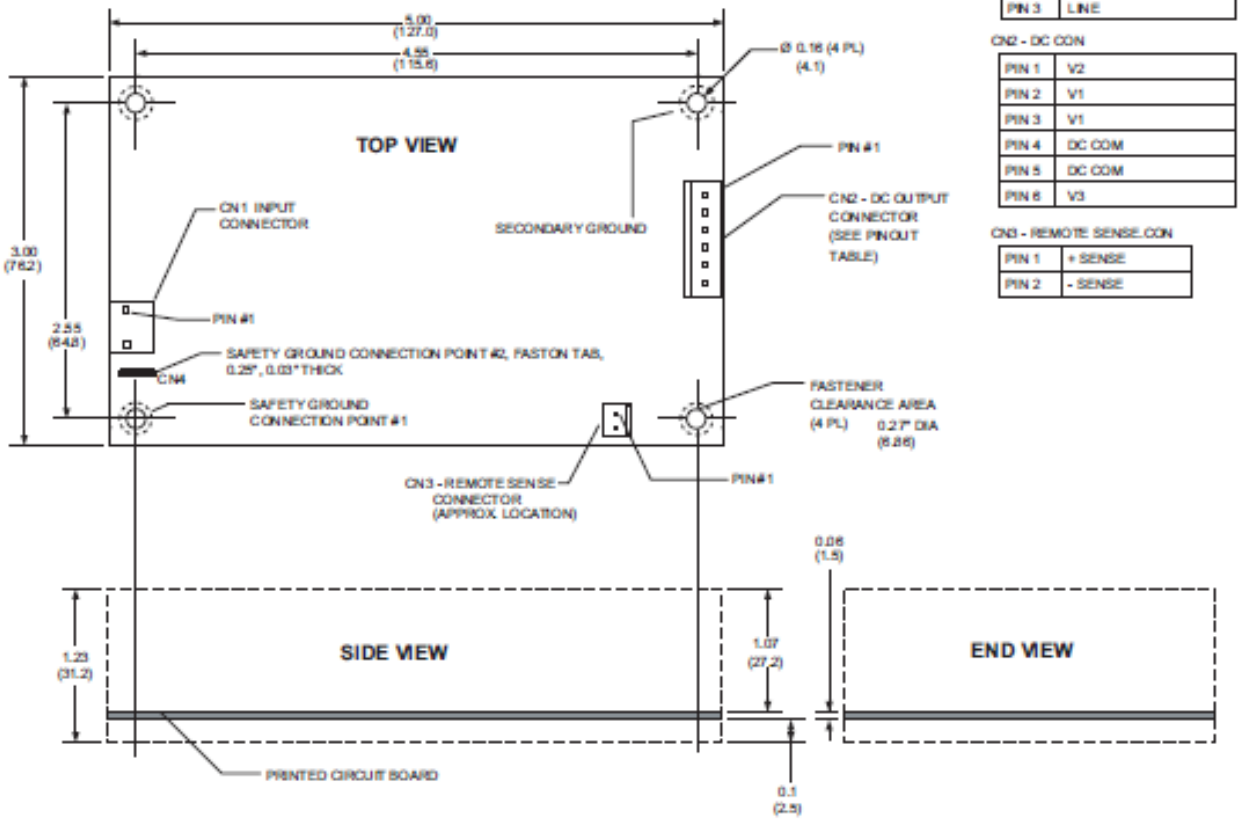
| | HOUSING | PIN |
|---|---|---|
| CN1 | MOLEX 09-50-8031 | 08-52-0113 |
| | LEOCO 3940S030000 | 3983TCB0000 |
| CN2 | MOLEX 09-50-8061 | 08-52-0113 |
| | LEOCO 3940S060000 | 3983TCB0000 |
| CN3 | MOLEX 22-01-3027 | 08-52-0113 |
| | LEOCO 2530S020000 | 2533TPB0000 |

NOTE: This is an outline drawing only. The detailed location of components is not shown.

**Overall Size: 3.00" x 5.00" x 1.23" (76.2mm x 127.0mm x 31.2mm) Weight: 0.51 lb (0.23 kg)**

## Mechanical Drawing

## (Triple-Output Models)




CN1 - AC CONN.

| | |
|---|---|
| PIN 1 | NEUTRAL |
| PIN 2 | MISSING PIN |
| PIN 3 | LINE |

CN2 - DC CON

| | |
|---|---|
| PIN 1 | V2 |
| PIN 2 | V1 |
| PIN 3 | V1 |
| PIN 4 | DC COM |
| PIN 5 | DC COM |
| PIN 6 | V3 |

CN3 - REMOTE SENSE CON

| | |
|---|---|
| PIN 1 | + SENSE |
| PIN 2 | - SENSE |

### RECOMMENDED MATING CONNECTORS

| | HOUSING | PIN |
|---|---|---|
| CN1 | MOLEX 09-50-8031 | 08-52-0113 |
| | LEOCO 3940S030000 | 3983TCB0000 |
| CN2 | MOLEX 09-50-8061 | 08-52-0113 |
| | LEOCO 3940S060000 | 3983TCB0000 |
| CN3 | MOLEX 22-01-3027 | 08-52-0113 |
| | LEOCO 2530S020000 | 2533TPB0000 |

NOTE: This is an outline drawing only. The detailed location of components is not shown.

NUCLEAR AND MEDICAL APPLICATIONS - Power-One products are not designed, intended for use in, or authorized for use as critical components in life support systems, equipment used in hazardous environments, or nuclear control systems without the express written consent of the respective divisional president of Power-One, Inc.

TECHNICAL REVISIONS - The appearance of products, including safety agency certifications pictured on labels, may change depending on the date manufactured. Specifications are subject to change without notice.

# Requirements Specification

## Overview

The number of people over 65 is increasing due to the aging of the Baby-Boomers, the generation of people born after World War Two. One of the greatest demands of this generation is medicine. People over the age of 65 buy 30 percent of all prescription drugs and 40 percent of all over-the-counter drugs (1). The average number of pills taken daily by people over the age of 65 is 2.9. More than one in five seniors take five or more different prescription drugs every day. Here is a table showing the number of drugs taken daily by seniors (2).

Table 1. Number of pills taken by people over 65

| Pills Taken | Percentage of Seniors |
|---|---|
| 0 | 18% |
| 1-2 | 36% |
| 3-4 | 25% |
| 5+ | 21% |

Keeping track of medication is a burden for the elderly. Arthritis, poor eyesight, poor hearing, and memory lapses can make it difficult for some older people to take their medications correctly. Studies have shown that between 40 and 75 percent of older people don't take their medications at the right time or in the right amount (1). The consequences for not taking medication properly can be fatal. When two or more drugs are mixed in the body, they may interact with each other and produce uncomfortable or even dangerous side effects (1). Medication users desperately need a product to keep track of their medication and administer the correct amount at the correct time.

Some people organize medication by putting it into a small container that is partitioned into seven smaller containers, each representing a different day of the week. This method is very tedious and also fails at organizing many varieties of medication. It does nothing to help people remember to take their medication. There is another device that allows a user to organize pills into 29 separate bins and set a timer that will alert the user when it is time to take their medication (3). The problem with this is that each bin only has enough space for three pills at the most, and the alarm can only be set to go off once a day. It also does not dispense the pills, but leaves them accessible to the user.

The Asklepius medicine dispenser will solve these problems, making it easier to organize medication. It will be quick, easy to setup, and will allow a person to stay organized for a month at a time. The device will also sound an alarm when it is time to take the medication. The Asklepius medicine dispenser is the superior alternative.

## Problem Statement

Taking the correct medication at the correct time is challenging for the elderly and can be a burden on loved ones. Not taking medication properly can be very dangerous and potentially fatal. The age 65 and over market demands a cost effective device that will keep track of and dispense the proper amount of medication at the right time. The device would serve solid, orally ingested tablets and capsules. Throughout the report, this medication will be referred to with the term pills.

## Customer Needs

The caretaker is the person who sets up the device and is assumed to have the technical skills of an average person, meaning anyone who can operate a computer to browse the internet and do basic things such as shopping online. The patient is the person receiving pills dispensed from the device and might have mental difficulties. The caretaker will organize pills into the device and then set it up to dispense a certain amount of pills at specified times. The customer needs shown below give a very general overview of the requirements that will be defined in more detail in the technical specifications section.

- The device needs to consistently dispense the amount of pills entered by the caretaker at the time entered by the caretaker. It needs to be completely reliable to ensure the safety of the patient.

- The device needs to service a large variety of pills. If there are many types of pills that are not serviceable by the device, then the device will not appeal to a large percentage of its target market.

- The device needs to be light enough for an average person to carry easily.
  The device needs to be portable and easy to handle. It needs to fit comfortably on an average kitchen counter top, which has 0.46 m (18 in) of space between the counter top and upper cabinets (4).

- The device needs to remain active at all times. Since the device will serve a critical application, the device needs to remain in operation in the event of a power failure.

- The device needs to alert the patient when a dosage is ready. It needs to use an alarm instead of more technically advanced methods due to the inferior technical knowledge of the patient.

- The device needs to be easy for the average person to set up. This means that it needs to be easy for the average person to insert pills into the device and program when they should be dispensed by the device.

- The internal components of the device need to be secure. This is to prevent unwanted access to the pills inside the device.
- The device needs to hold a month's supply of pills. This will increase the ease of use for the caretaker.
- The device needs to notify the caretaker when the patient does not take their pills.

## Operational Description

Pills Loading Process:

- Unlock and open the door of the device to access pill storage bins inside the device.
- Insert each type of pill into one of the storage bins. Be sure to only put one type of pill into each bin.
- Close and lock the device.
- Make sure the device is plugged into a power outlet and the power is switched on.

Programing Process:

- Program the device using a laptop computer wirelessly connected to the device.
- Specify the type of pills in each storage bin.
- Specify the doses and the times these doses are to be taken.
- Enter the email address you would like to be notified at in the case that the patient does not receive their pills.

Patient Pill Retrieval Process:

- Place RFID chip within four inches of the RFID reader to gain access to the pill retrieval area. This will also turn the alarm off.
- Grab pills from the pill tray.

## Technical Requirements

A pills dispenser project, titled PEZ, was completed by one of the 2010-2011 Senior Design groups. Some of our technical specifications were selected with intentions of making improvements on last year's project.

- It will successfully provide the proper pills specified by the caretaker in a minimum of 40 out of 40 tests.
- It will be able to service pills ranging from 10 mg to 1 g. For the purposes of these technical requirements, pills' sizes will be defined by two dimensions and a shape. One dimension will be the smallest dimension of the pill. The other will be the largest dimension of the pill. The device will be able to operate on pills with small dimensions between 0.5 cm (0.2 in.) and 1 cm (0.4 in.) It will be able to operate on pills with large dimensions underneath 2.5 cm (1 in.) The device will operate with pills shaped as tablets, capsules, and ovals.
- It will weigh less than 130 N (30 lbf).
- Its dimensions will be less than 0.46 m (18 in) high, 0.38 m (15 in) wide, and 0.38 m (15 in) long. Last year's dimensions were, 0.54 m (21.25 in), 0.44 m (17.5 in), and 0.48 m (19 in) respectively. The spatial dimensions of the object are defined as the smallest cube needed to encapsulate the object. For example, the height of the device is the distance from the base of the device to the tallest point on the device.
- A back up battery will be used as a fail-safe in the event of a power outage. It will be able to power the device for one week.
- The device will have an alarm that will sound when the pill is being dispensed. The alarm will have an intensity between 80 and 90 dB.
- An average person will be able to program the device in less than 5 min.
- The device will have a lock to prevent unwanted access to the interior of the device.
- The device will store 90 pills of each medication.
- The device will be able to connect to a WEP, WPA and WPA2 secured Wi-Fi networks.
- The device will email the caretaker when the patient's pills are not taken within 30 minutes of the alarm initially sounding.

Table 2. Technical Specifications

| No. | Metric | Value | Units |
|---|---|---|---|
| 1 | Total Weight | < 130 | N |
| 2 | Device Size | 0.46 (H) x 0.38 x 0.38 | m |
| 3 | Time to program a medication | < 5 | min |
| 4 | Amount of pills in each bin | 90 max | pills |
| 5 | Intensity of the alarm | 80-90 | dB |
| 6 | Time for battery to discharge | 1 | week |
| 7 | Weight of pills | 10-1000 | mg |
| 8 | Lock | Locked/Unlocked | |
| 9 | Successful dispensing tests | 100 | % |
| 10 | Time to alert caretaker | 30 | min |
| 11 | Wi-Fi connection | Connected/Unconnected | |

Table 3. Needs-Metrics Matrix

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Weight | Device size | Time to program a medication | Amount of pills | Intensity of the alarm | Time for battery to discharge | Weight of pills | Lock | Successful dispensing tests | Time to alert the caretaker | Wi-Fi connection |
| 1 | Portable and easy to handle | ● | ● | | | | | | | | | |
| 2 | Easy to program | | | ● | | | | | | | | |
| 3 | Large variety of medication | | | | | | | ● | | ● | | |
| 4 | Alert the patient when a dosage is ready | | | | | ● | | | | | | |
| 5 | Remain active at all times | | | | | | ● | | | | | |
| 6 | Month's supply of medication | | | | ● | | | | | | | |
| 7 | Internal components of the device only accesible to the caretaker | | | | | | | | ● | | | |
| 8 | Consistently provide medication | | | | | | | | | ● | | |
| 9 | Alert the caretaker if a dosage has not been taken | | | | | | | | | | ● | ● |

## Deliverables

- Pills dispenser device
- Systems capability specifications
- Detailed schematic and final report on device functionality
- User manual
- Parts manual and corresponding budget

## Testing Plan

- The general testing procedure for the efficacy of the dispensing mechanism of the device will be carried out as follows:
    - Pills will be inserted into the device. For the purpose of this test, we will not limit ourselves to actual pills, we will allow for other forms of solid, orally ingested tablets and capsules such as mints or candies.
    - The device will be programmed to dispense the pills at a set time. The pills will then have to be dispensed within five minutes of the set times.
    - The success criterion described in the following paragraph will be determined by visual observation by one of the team members.

  The success of the test is dependent on two factors. First the operation will be counted as being on time if the pills are dispensed within five minutes of the programmed time. Second, the operation must result in the amount and type of pills being dispensed as programmed by the caretaker. If both of these requirements are successfully met, then the result of the test is successful. Otherwise, the test is not successful.

  40 tests will be performed which will fall into one of four categories. Each category tests pills that fall within a certain range of masses. The categories are: 10 mg to 250 mg, 250 mg to 500 mg, 500 mg to 750 mg, and 750 mg to 1 g. For example, a pill that weighs 100 mg is a category one pill. The 40 tests will be divided evenly between these four categories, meaning that 10 tests will be done with pill sizes in only one category. The device must perform successfully in 40 consecutive tests, with the variability of pill types as described above.

- The device will be weighed with a bathroom scale to determine that it meets the weight requirement. The device will be weighed four times. The mean of these measurements must be under the requirement listed in the technical requirements.

- The device will be measured to determine that it meets the volume requirements. These measurements will be made with a measuring tape. The height, width, and length of the device will be measured four times each. The mean of these measurements must be less than requirements listed in the technical requirements. For example, the height of the device will be measured four times with a measuring tape. These four measurements will be averaged and must be less than 0.46 m. The definition of the height, weight, and length is described in the technical requirements.

- The life of the back-up battery will be tested. The battery will be fully charged and the device will undergo eight days' worth of dispensing in a 24 hour period. This assumes the worst case scenario of dispensing a pill from every bin three times a day, which adds up to dispensing a pill from each bin 24 times. We will do eight days' worth rather than seven to account for the total time throughout the week that the device is not dispensing.

- The intensity of the alarm will be measured with a digital-display sound-level sensor from radio shack (5). The sensor reads from 50 to 126 dB and will be placed within one meter of the device. The alarm intensity will be measured from within this distance 10 times. The mean of these measurements must fall within the range listed in the technical requirements.

- Random people will be asked to program the device. The number of people that perform this test must at least be above 10. The time it takes a person to program the device will be recorded by one of the team members. The time needed to program the device does not include the time taken to learn how to use the device. The programming time of all of the testers will be averaged. To successfully meet the ease of use requirement, this average must be under five minutes.

- To determine that a container holds a month's supply of pills, 90 pills will be poured into a container. If all of the containers are the same size, then this test will only need to be performed on one of the containers. If the containers are different sizes, then this test will be performed on the smallest container. The pills used in this test must be category four. To successfully meet this test, 90 pills must fit into the container without spilling over the top.

- We will connect the device to a WEP, WPA and WPA2 secured Wi-Fi network five times each. If the device successfully connects to the Wi-Fi network five times consecutively for each type, it has passed this requirement.

To determine if the device successfully emails the address given by the caretaker when pills are not taken, we will purposefully allow the alarm time to run out 10 times after dispensing pills. If an email is sent for all 10 tests consecutively, this requirement has been met. For normal operation, the time that the device would wait before sending an email will be 30 minutes; however, for the purpose of this test that time will be reduced to 1 minute.